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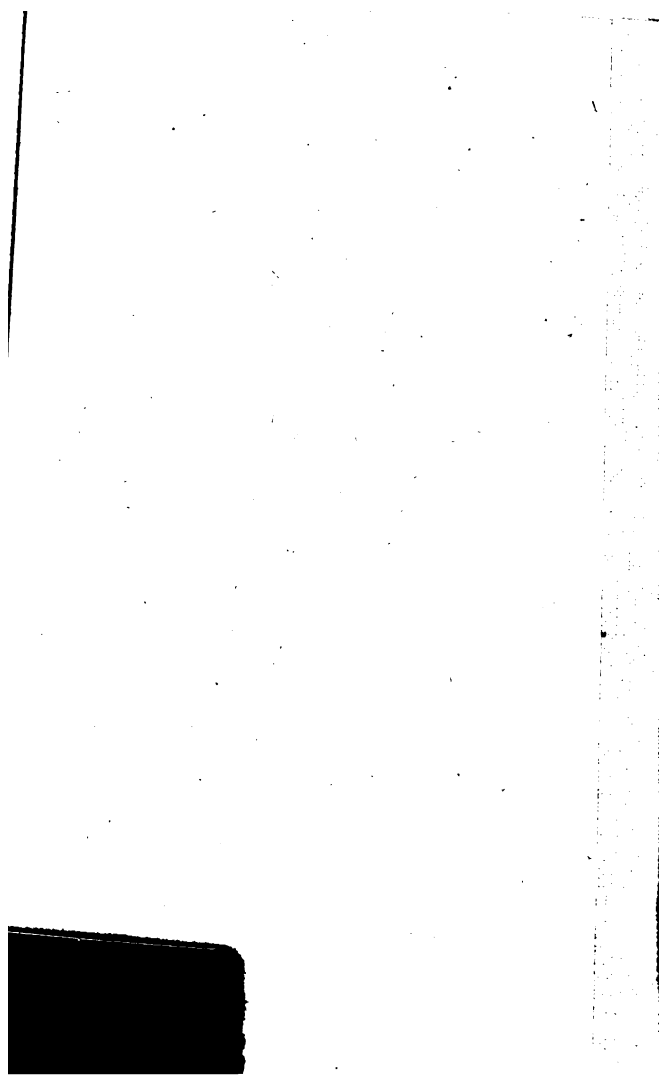
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**AN**  
**ELEMENTARY COURSE**  
**OF**  
**NATURAL AND EXPERIMENTAL**  
**PHILOSOPHY.**

**VOL. II.**

**LONDON:**  
**A. and G. A. SPOTTISWOODE,**  
**New-street-Square.**

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**ELEMENTARY COURSE**  
OF  
**NATURAL AND EXPERIMENTAL  
PHILOSOPHY,**

**FOR THE USE OF BEGINNERS.**

In which the Principles of the Physical Sciences  
are familiarly explained and illustrated by numerous  
Experiments and Diagrams.

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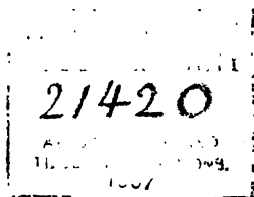
**VOL. II.**

**ELECTRICITY.  
MAGNETISM.  
EXPERIMENTAL CHEMISTRY.**

**VOLTAIC ELECTRICITY.  
ELECTRO-DYNAMICS.**

**LONDON:  
LONGMAN, BROWN, GREEN, AND LONGMANS,  
1855.**

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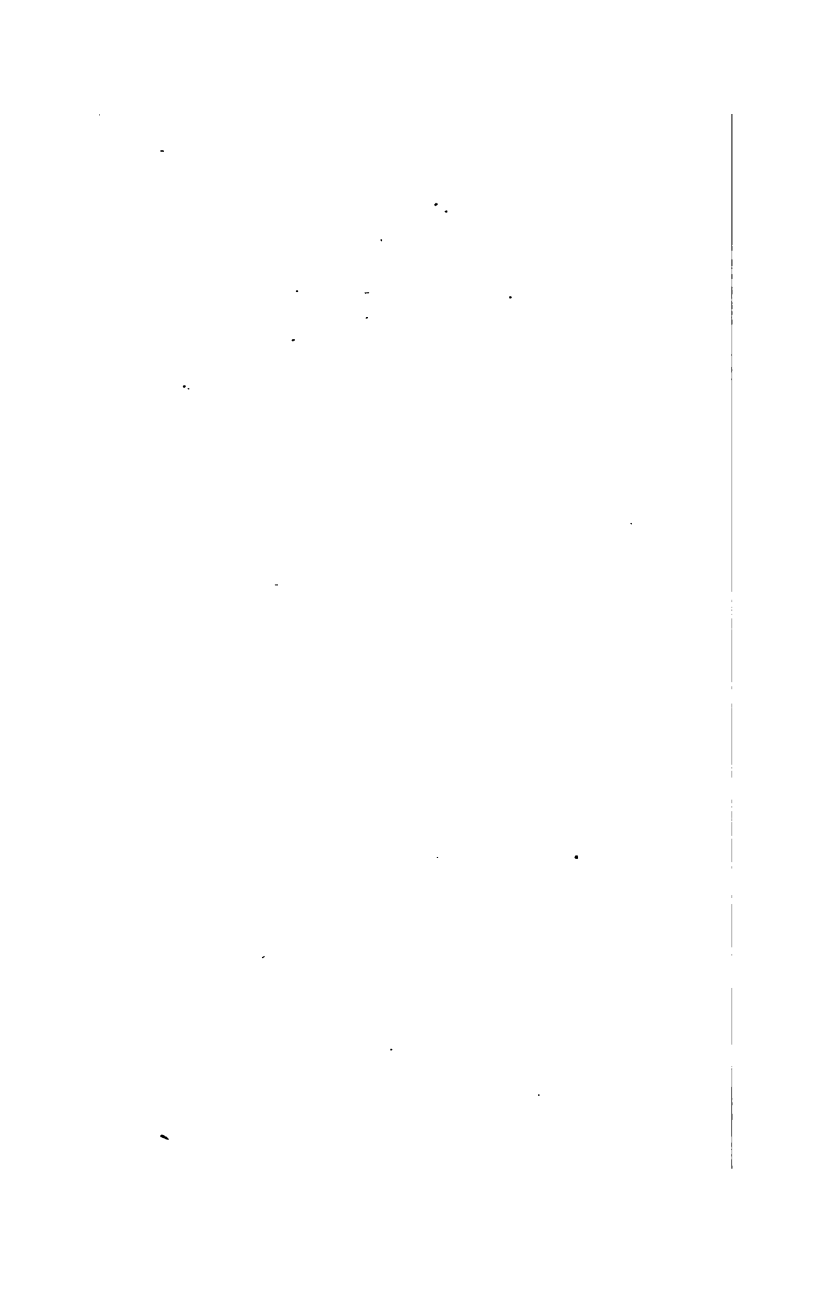
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# ELECTRICITY.

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## PRELIMINARY VIEWS AND EXPERIMENTS.

WHAT is electricity? It is a subtile fluid which pervades all nature, and which becomes known to us by its peculiar properties, or by the way in which it affects our senses. Lightning is electricity; — in the thunder-storm nature generates the electric fluid on a mighty scale. Electricity is most easily generated by friction, or, to speak more definitely, it is rendered apparent to our senses when certain bodies are rubbed against each other. Electricity appears to exist in all bodies in a latent or hidden state, but friction, and other causes, disturb this state of quiescence or inactivity. There are various means of generating electricity besides friction, — for instance heat, chemical action, or pressure will generate it; but we purpose first to show its various properties when it is generated by friction.

EASY COURSE OF EXPERIMENTS, WITH SIMPLE PRINCIPLES DERIVED FROM THEM.

The following electrical experiments may all be performed by any intelligent person, with no other apparatus than what may be obtained in any

ordinary dwelling-house. All the experiments here described have been repeatedly performed by the author with invariable success. Many of them, he believes, are new and simple, and highly calculated to interest young persons, from the very fact that they have it in their power to repeat the experiments at any time they may wish to do so.

*Bodies which are electrified, or which contain free electricity, attract and repel light substances; and when the electricity is generated in a sufficient quantity, luminous sparks, accompanied by a sharp cracking noise, pass from the electrified body to any body which is not electrified.*

These fundamental facts of electricity are illustrated by the following experiments:—

*Exp. 1.* Rub a stick of sealing-wax, or a dry glass tube, with a warm piece of flannel or silk;—electricity is generated. Hold the excited stick of sealing-wax over some cuttings of light paper, or any other light substances; the bits of paper will be attracted by the sealing-wax, and will sometimes fly and dance up and down.



Fig. 1.

Bring the excited sealing wax before your eyes; a sensation is felt as if spiders' webs were drawn across your face.

Bring the sealing-wax under your nose; you feel a faint smell like phosphorus.

Suspend a feather or a little cork ball by a silk thread, as shown in *fig. 2.*; bring the excited sealing-wax near the little ball;—it is first attracted, and then it is repelled.

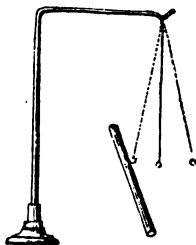


Fig. 2.

Those substances which readily yield electricity by friction have been called *electrics*. But it has recently been found that all substances possess this property in a greater or less degree.

*Exp. 2.* Suspend two feathers (or two light cork balls) by silk threads, as shown in *fig. 3.*; bring the excited sealing-wax near the feathers; they are first attracted to the sealing-wax, and then they are repelled from it; and they will finally be found to diverge or fly from each other, as shown in the figure.

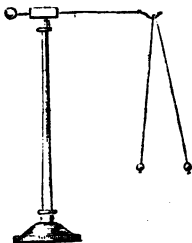


Fig. 3.

Here it will be observed, that the electrified body first attracts the feathers, and then when they become electrified, in the same way as the sealing-wax, they are repelled by it, and mutually repel each other.

*Exp. 3.* Bring the excited stick of sealing-wax near a light downy feather, floating in the air; the feather will first be attracted to the sealing-wax, and then repelled from it. As the sealing-wax is moved towards the feather, it will continue to fly away. In this way the feather may be driven about the room. If the feather should touch any body not electrified, it will fly back to the sealing-wax again. Or if an excited glass tube be brought near the feather, it will be attracted.

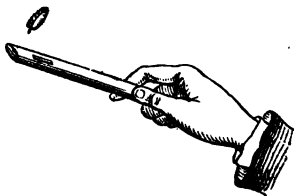


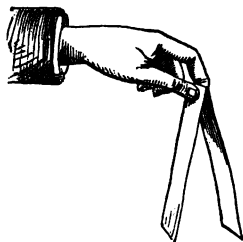
Fig. 4.

Here the excited sealing-wax first attracts the

feather ; and then, when the feather becomes electrified in the same way as the sealing-wax, it is repelled.

*Exp. 4.* Take up a black cat, which has been lying before the fire, hold it by the throat with one hand, and with the other hand rub it smartly along the back ; electricity will be generated, the hair will become so excited and charged with the electrical fluid that a faint shock may sometimes be felt, and a succession of sparks may be seen, if the experiment is performed in the dark.

*Exp. 5.* Take two strips of brown paper, about 9 inches long and 2 inches wide ; warm them, and hold them by the finger and thumb of the left hand ; rub them briskly, by inserting the fore-finger of the right hand between them, and then drawing it sharply from end to end ; the strips of paper will be powerfully electrified, and will diverge from each other, as shown in *fig. 5*. They repel each other because they are electrified in the same way.



*Fig. 5.*

Bring the hand between them when thus repelled, and they will both be attracted by the hand.

*Exp. 6.* Lay the two strips of brown paper, the one over the other, on a smooth table ; rub them with the hand, or, what is still better, draw the edge of an ivory rule or scale over them for a few times ; lift them from the table, and then separate them from each other ; they will attract each other very powerfully.

In the last experiment they repelled each other

because they were electrified in the same way; but here they attract each other, because they are electrified in different ways. It will be afterwards shown, that whilst the bottom piece of paper is *positively* electrified, the top piece is *negatively* electrified.

The two foregoing experiments may be performed with silk ribbons, or with strips of thin sheet gutta-percha.

In the place of the hand, an old fur cuff, or a hare's skin, or indian-rubber, or a piece of warm flannel, or an ivory scale may be employed as the rubber.

*Exp. 7.* Take two pieces of lump sugar, and rub them together in the dark; they will appear covered with a beautiful lambent flame of electric light.

*Exp. 8.* Take a piece of stout common brown paper (or a sheet of thin gutta-percha), about a foot long and nine inches broad; hold it before the fire until it is quite hot\*, lay it upon the table, and rub it briskly for a few times with the palm of the hand; the paper will become powerfully electrified.



*Fig. 6.*

\* Gutta-percha should never be heated.

sheet of paper, or gutta-percha, described in *exp.* 8. or 9., upon the tea-tray bring the knuckle near to the tea-tray, and an electric spark will be received; quickly withdraw the paper, and again apply the knuckle, and another spark will be received; replace the paper and then apply the knuckle, and another spark will be perceived, and so on for at least a dozen times.

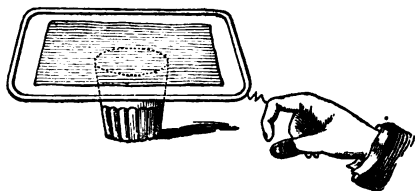


Fig. 9.

*Exp. 12.* Take a small splinter of wood, about 9 inches long; fix corks to its extremities; suspend it from its middle by a silk thread; bring the excited stick of sealing-wax, or brown paper, near to one of the corks; it will be attracted, and by moving the electrified body in a circle, the cork, being constantly attracted, will appear to revolve on the thread as an axis.

*Exp. 13.* Make a notch in the middle of the rod, described in the last experiment, and balance it on the edge of a dinner knife, *C*, as shown in *fig. 10.* (the balance of the rod is easily adjusted by pushing either the one cork or the other nearer to the centre of the splinter). Bring the excited brown paper over the

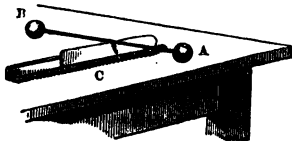


Fig. 10.

cork A, and it will be attracted; now place the excited brown paper over the cork B, and it will, in its turn, be attracted, and so on; thereby giving an oscillating motion to the rod AB, on the edge C. This experiment exhibits electrical attraction in a striking manner, being conducted on a large scale.

*Exp. 14. To make two forks revolve by electrical attraction.*—Stick two small forks, A and B, into a cork C, as shown in *fig. 11.*; stick a sewing needle, with its point outwards, into the cork; poise the whole on the point of the needle, standing on the top of a wine glass, G; bring the excited sealing-wax, or brown paper, near one of the forks, and make it revolve, as in *exp. 12.*

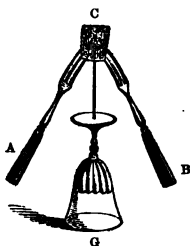


Fig. 11.

*Exp. 15.* Blow out a lighted candle having a long snuff; bring an excited rod of sealing-wax near to the wick, as shown in *fig. 12.*; the smoke is attracted by the sealing-wax, and sparks of fire appear to fly towards it.

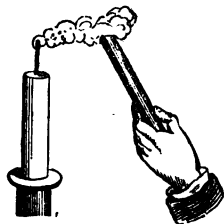


Fig. 12.

*Exp. 16.* Support a warm pane of glass upon two books, one at each end; place some dry bran, or cuttings of fine paper, or light pith or cork balls, beneath the glass, and briskly rub the upper side with a warm piece of flannel or black silk; the bran will dance up and down with great rapidity.

This experiment was first made by Newton. It was important at the time of its discovery, inas-

much as it showed, what was not known before, that an electrical body became electrified on the side contrary to that which was excited.

CONDUCTORS AND NON-CONDUCTORS OF ELECTRICITY.  
—INSULATION.

The metal tea-tray of *exp.* 11. was placed upon a glass tumbler, because glass is a non-conductor of electricity; and, in like manner, the feathers of *exp.* 2. were suspended by silk threads, because dry silk is a non-conductor of electricity. If the feathers had been suspended by a metallic wire, in the place of silk, they would not have diverged from each other in the manner described, for metals conduct the electric fluid.

The electric fluid does not diffuse itself over the surface of a non-conductor, but remains confined strictly to that portion of the surface which first received it; thus, when one end of a stick of sealing-wax is rubbed, that extremity becomes highly electrified, whilst the other extremity remains in its natural state. On the contrary, conductors freely convey the electric fluid from one part of their surface to another, and thus the electric fluid instantaneously diffuses itself uniformly over the whole surface of the conductor, just as water would spread itself over a level surface. All metallic bodies are excellent conductors, and water, wood, &c., as well as all substances in a damp state, readily conduct electricity. The earth is the great reservoir and conductor of electricity. When any electrified body is suspended from, or supported by a non-conductor, the body is said to be **INSULATED**. All non-conductors, therefore, are called **INSULATORS**. Glass rods, silk threads, sealing-wax, and fine threads of sealing-wax, are the insulators most commonly used

in performing electrical experiments. All these substances become conductors when they are in a damp state; hence the necessity of having all our insulators perfectly dry and warm. Sealing-wax is the best of all insulators, because it does not readily become covered with moisture. The author has found that, for conducting delicate experiments, there is no insulator to be compared with a fine thread of sealing-wax or gum-lac.

Bodies differ very much, as well in their conducting as in their insulating powers. Of all bodies metals are the best conductors, and resinous bodies are the best insulators or non-conductors. The bodies in the following list possess these powers, in the order in which they are named.

*Classification of Conductors according to their conducting power.*

All the metals.  
Charcoal.  
Plumbago.  
Acids  
Metallic ores.  
Animal fluids.  
Water, and all damp substances.  
Ice above 13°, Fahrenheit.  
Snow.  
Living animals and vegetables.  
Flame, smoke, and steam.  
Soluble salts.  
Rarefied air.  
Vapours of ether and alcohol.  
Damp earth and stones.  
Powdered glass.  
Flowers of sulphur.

*Classification of Insulators according to their insulating power.*

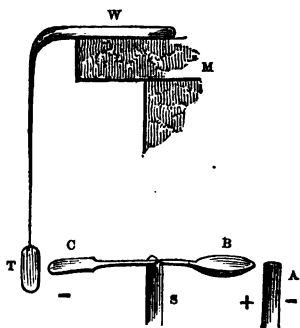
Gum-lac, gutta-percha.  
Amber.  
Resins, sulphur, wax, jet.  
Glass, and all vitrifications.  
Mica.  
Diamond, transparent gems.  
Raw silk, bleached silk, dyed silk.  
Wool, hair, feathers.  
Dry paper.  
Parchment, leather.  
Atmospheric air, when dry.  
All dry gases.  
Baked wood.  
Porcelain and dry marble.  
Camphor, indian-rubber.  
Lycopodium.  
Dry chalk, lime, phosphorus.  
Ice below 13° Fahrenheit.  
Many dry transparent crystals.  
Oils, dry oxides of metals.

Conducting substances were, at one time, called *non-electrics*, and non-conductors were called *electrics*; but the distinction is not founded on fact, because conducting substances, when insulated, will yield electricity by friction; and besides, the capacity of a substance for yielding electricity by friction does not seem to depend upon the insulating or non-conducting power of the substance.

The atmosphere manifestly belongs to the class of non-conductors; if this had not been the case, no electrified body could have retained its electricity for any length of time. When air becomes rarified, it loses its insulating property; thus, an electrified body soon loses its electricity when placed in the exhausted receiver of an air-pump. The electric fluid spreads itself in a thin coating over the surface of the electrified body, and it is prevented from escaping by the pressure or tension of the surrounding air; when this pressure is reduced beyond a certain degree, the electricity escapes from the surface.

#### ELECTROSCOPES.

Electroscopes are instruments used for detecting the presence of electricity in bodies; such as the suspended pith balls represented in *fig. 3*. By means of an electroscope, we can readily show that there are two kinds of electricity; the one being called positive electricity, and



*Fig. 13.*

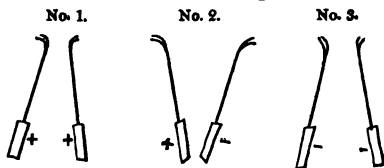
the other negative electricity. There are various electroscopes, but the following one is easily made, and is quite delicate enough for all ordinary electrical experiments.

**TO MAKE A SIMPLE ELECTROSCOPE.**—Take a narrow strip of tinfoil; melt the end of a stick of sealing-wax; attach it to one end of the tinfoil, and draw the wax out into a fine thread, as shown in *fig. 13.*, where *t* represents the tinfoil, and *w* the sealing-wax; place the stick of sealing-wax on the mantle-shelf *M*, and you will have constructed a very useful electroscope, with which the following demonstrative experiments may be successfully performed.

**THERE ARE TWO KINDS OF ELECTRICITY.**

Make two simple electroscopes; excite a stick of sealing-wax, and also a dry glass tube; the electricity of the sealing-wax, which is said to be *negative*, will be different from the electricity of the glass, which is said to be *positive*, as may be shown by the following experiments:—

*Exp. 1.* Touch the strips of tinfoil with the excited glass tube, bring them near to each other, and they will fly from each other, as shown in No. 1., *fig. 14.* Here the bodies repel each other, be-



*Fig. 14.*

cause they are electrified in the same way, that is to say, they are both in a state of positive or plus, +, electricity.

*Exp. 2.* Perform the same experiment with the excited sealing-wax, and the strips of tinfoil will repel each other, as shown in No. 3., *fig. 14.* Here the bodies are both in a state of negative or minus, —, electricity.

*Exp. 3.* Touch one of the strips of tinfoil with the excited glass tube, and touch the other strip with the excited stick of sealing-wax; bring the strips thus electrified near each other; they will be powerfully attracted to each other, as shown in No. 2., *fig. 14.*, thereby proving that the electricity generated by the friction of glass is different from the electricity generated by the friction of sealing-wax.

These experiments may be readily performed with one electroscope in the following manner:—

*Exp. 4.* Bring the excited stick of sealing-wax near the strip of tinfoil; it will be first attracted, and then it will remain permanently repelled. Any other excited stick of sealing-wax, or any excited resinous substance will repel the electrified strip. Now bring an excited glass tube near to the electrified tinfoil; it will be instantly attracted.

From these experiments we derive the following law, relative to the two kinds of electricity:—

BODIES ELECTRIFIED IN THE SAME WAY REPEL ONE ANOTHER; BODIES ELECTRIFIED IN DIFFERENT WAYS ATTRACT ONE ANOTHER. Or we may express this law by simply stating, that LIKE ELECTRICITIES REPEL, AND UNLIKE ATTRACT.

By this law of electrical polarity we may easily ascertain to which kind of electricity any excited body belongs.

*Exp. 1.* Suppose we wish to know whether the excited brown paper of *exp. 5.*, p. 4., is positive or negative.

Touch the strip of tinfoil *r*, *fig. 13.*, with an ex-

cited stick of sealing-wax, and the tinfoil will be negatively electrified : now bring the excited brown paper near to the strip of tinfoil ; it is repelled ; therefore the paper is electrified in the same manner as the sealing wax, that is, it is in a state of negative electricity.

Or we may proceed as follows :—Touch the tinfoil of the electroscope with an excited glass tube ; bring the excited paper near to the tinfoil ; it is instantly attracted, thereby showing that the electricity of the excited paper is unlike the electricity of the excited glass, that is, the electricity of the paper is negative.

*Exp. 2.* Perform the same experiment with excited sulphur. It will be found to possess negative electricity.

*Exp. 3.* Rub a glass tube with a black cat's skin ; test the electricity of the glass ; it will be found to be negative, thereby showing that the same substance may be positively or negatively electrified, according to the nature of the rubber.

*Exp. 4.* Test the electricities of the two sheets of brown paper of *exp. 6.*, p. 4 ; the upper sheet will be negative, while the bottom sheet will be positive.

After separating the sheets of brown paper, place them on opposite sides of the tinfoil ; it will fly with great rapidity backwards and forwards from the one sheet of paper to the other.

*Exp. 5.* Hold an excited stick of sealing-wax and an excited glass rod near to the tinfoil of the electroscope ; the tinfoil will fly backwards and forwards from the one to the other. Perform the same experiment with the flying feather of *exp. 3.*, p. 3.

TO SHOW THAT ELECTRICITY REMAINS ON THE SURFACE OF A NON-CONDUCTOR WHEN IT IS ELECTRIFIED, THAT IS TO SAY, THE ELECTRIFIED FLUID DOES NOT PASS FROM ONE PART OF THE SURFACE TO ANOTHER PART.

*Experiment.* Excite the *whole* surface of a piece of sealing-wax with dry silk; run the fore-finger down *one side* of the excited sealing-wax; touch the tinfoil of the electroscope with that side of the sealing-wax from which the electricity has not been taken away, then the tinfoil will be repelled; turn the sealing-wax round, then the tinfoil will no longer be repelled. Here it will be seen that the electricity does not spread itself from one side of the sealing-wax to the other side.

THE ELECTRICITY OF THE RUBBER IS DIFFERENT FROM THE ELECTRICITY OF THE BODY WHICH IS RUBBED.

*Exp. 1.* Lay a piece of dry silk upon the table, and rub it with a stick of sealing-wax; lift up the excited silk by one corner, and touch the tinfoil of the electroscope with it, then the tinfoil will be charged with positive electricity; bring the excited sealing-wax near to the tinfoil, and it will be powerfully attracted, thereby showing that while the sealing-wax is in a *negative* state of electricity, the silk is in a *positive* state.

*Exp. 2.* Tie a piece of silk or flannel to the end of a stick of sealing-wax; rub a warm plate of glass with the insulated silk, taking care to hold the rubber by the insulating handle; test the electricity of the rubber and the excited glass by means of the electroscope, and it will be found that the silk rubber is negative, while the glass is positive.

*Exp. 3.* Rub a sheet of brown paper in the same manner. In this case the silk rubber will be positive, and the sheet of paper negative.

## THEORIES OF ELECTRICITY.

These experiments led some philosophers to consider that there was only one electric fluid, and that it existed in the glass, which was rubbed, in excess, or in a plus state, while it existed in the rubber in deficiency, or in a minus state. According to this theory, the friction deprives the rubber of a portion of its natural electricity, and transmits it to the glass, which thereby receives more than its natural share. This explains the use of the terms *positive* and *negative* electricity. However, as we shall afterwards show, it seems to be more simple for us to regard electricity as consisting of two fluids, which mutually attract each other, but, at the same time, each fluid is self-repellant—that is to say, its own particles repel one another. This theory fully accounts for the electrical attractions and repulsions; for when the electric fluids in two bodies are unlike, the bodies attract each other, by virtue of the mutual attraction of the two fluids; and, on the contrary, when the electric fluids in the two bodies are like, the bodies repel each other, by virtue of the repellant property of the particles of the same fluid. When equal portions of the two fluids unite, they neutralise each other, and the electricity is then in a neutral or quiescent state, which is the usual state in which electricity exists in bodies. Friction disturbs the equilibrium of the two fluids, by separating the one from the other: the positive fluid attaches itself to the glass, while the negative fluid attaches itself to the rubber. The two fluids, in the natural state of bodies, as it were

hold each other in a state of inaction, and electricity is then said to be latent or hidden.

THE SINGLE FLUID THEORY was adopted by Franklin, and after him by most of the English electricians, until very recently, when THE THEORY OF TWO FLUIDS, as above explained, which had been generally adopted on the continent, became more popular amongst us. It must, however, be remembered that the great use of theory in this subject, is to group and classify the vast accumulation of facts which have been brought to light.

#### CONDUCTION AND INDUCTION.

*Experiment.* Support a teaspoon, B C, or any thick metal wire, upon a stick of sealing-wax, s: this can easily be done by melting the wax, and fixing the spoon to it, as shown in *fig. 13.*, page 12. The spoon will thus form an insulated conductor.

(1.) Hold the conductor B C by the insulating stick s; bring the extremity C near to the tinfoil T of the electroscope; then *touch* the opposite extremity B with an excited stick of sealing-wax; the tinfoil will be attracted and then repelled. Here the metal B C conducts or conveys the electricity from the sealing-wax A to the tinfoil T. This is an example of CONDUCTION; B C may be any conducting substance.

If the intervening substance B C were glass, or any other non-conductor, the tinfoil would not be affected by the contact of A with the extremity B.

(2.) Bring the extremity C, of the conductor, at the distance of about half an inch from the tinfoil; hold the excited stick of sealing-wax A at about the same distance from the extremity B; then T will be electrified negatively, which can readily be tested in the usual way. This is an example of electrical INDUCTION: Take A away and all signs

of electricity will have disappeared from the conductor B C. Here the electricity is conveyed or transmitted from the electrified body to the tinfoil through the air, and not by the contact of the conductor with the electrified body. Electrical induction, then, takes place, when electricity is transmitted from one body to another body at some distance from it. The phenomena here exhibited may be explained as follows:—

The negative electricity on A repels the negative electricity in the conductor B C, and attracts its positive electricity; the consequence is the equilibrium of the two fluids in the conductor is destroyed, the negative fluid flies towards the extremity C, and the positive fluid is attracted towards the extremity B. Hence the tinfoil is first attracted towards C, and then repelled from it. And, upon withdrawing the conductor, the tinfoil will remain electrified negatively. To prove this, bring an excited stick of sealing-wax towards the tinfoil T, and it will be repelled.

(3.) Perform the same experiment with an excited glass tube A. In this case the extremity C will be positive, and the tinfoil will be charged with positive electricity.

(4.) Repeat *exp.* 2., and before taking the electrified sealing-wax A away, *first* touch C, and *then* take A away; the conductor will remain positively electrified, which will be shown by its now attracting T. If we touch the extremity B, the conductor will remain electrified negatively.

These effects may be readily explained. When we touch the extremity C we take away the free negative electricity, and then when A is taken away an excess of positive electricity remains in the conductor. In like manner when we touch the extremity B we take away the free positive electricity,

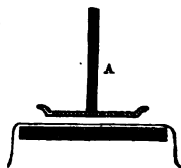
and then when A is taken away the conductor B C remains charged with negative electricity. The truth of these results may be readily verified in the usual way. Observe that the tinfoil T will always remain charged with the electricity of the extremity C of the conductor.

Electrical attractions are readily explained upon the principle of induction: by the action of induction, the body which is attracted is in a different state of electricity from that of the body charged with the electricity.

The following apparatus depends upon the principle of induction.

#### TATE'S SIMPLE GUTTA-PERCHA ELECTROPHORUS.

Take a toy tin plate, costing one penny; heat the bottom of the plate over the flame of a candle, and fix a stick of sealing-wax, A, as shown in *fig. 15.*, to its upper surface; lay a sheet of gutta-percha (or a sheet of warm brown paper, as the case may be) upon a smooth table, and excite the sheet in the usual way; place the tin plate upon the surface of the gutta-percha, and, after touching the plate with the finger, lift it off the gutta-percha, by means of the insulating handle; apply the knuckle to the tin plate, and a spark of positive electricity will be received. This may be repeated for about a hundred times, without any sensible diminution in the size of the spark.



*Fig. 15.*

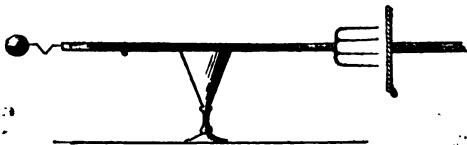
Here the friction of the gutta-percha generates negative electricity; and therefore, when we touch the plate, we take away a certain portion of negative electricity from it, and consequently when the plate is raised, it must contain an excess of positive electricity.

In order to give a continuous charge to a conductor, place the insulated tea-tray, represented in *fig. 9.*, directly above the edge of the plate *A* of the electrophorus, so that when the plate is lifted off the sheet of gutta-percha it shall strike against the edge of the tea-tray. In this way a rapid succession of sparks will be transmitted to the tea-tray, which will, consequently, become powerfully charged with positive electricity. An electrical jar, having its knob placed near to the edge of the tea-tray, will be soon charged with positive electricity.

By means of this electrophorus, the following demonstrative experiments may be readily performed.

TO SHOW THAT POINTED CONDUCTORS DRAW OFF ELECTRICITY FROM AN ELECTRIFIED BODY.

Place a common toasting-fork upon a dry wine-glass, as shown in *fig. 16.*; bring the electrified plate of the electrophorus near to the points of the fork, then a spark may be taken from its opposite extremity.



*Fig. 16.*

TO EXHIBIT ELECTRICAL INDUCTION AND CONDUCTION.

Place a poker upon a dry wine-glass, as shown in *fig. 17.*, touch one extremity of the poker with the electrified plate of the electrophorus, and a

spark may be received from the opposite extremity, thereby showing that the iron is a conductor of electricity.

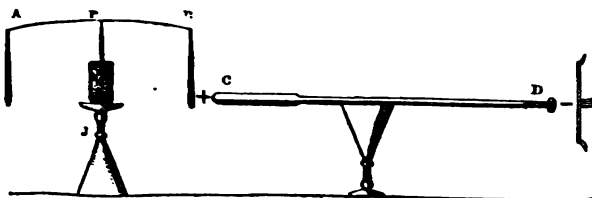


Fig. 17.

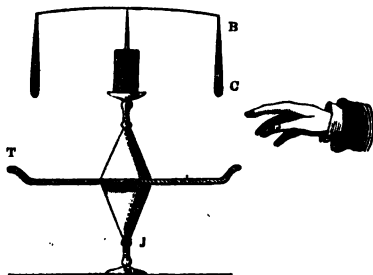
To show the induction of electricity in this case: Bring the electrified plate of the electrophorus near to one extremity, D, of the poker, but not so near as to transmit a spark; then a spark of positive electricity may be received from the opposite extremity C.

*The tinfoil needle electroscope.*—In order to render the law of induction more apparent, construct an electroscope, A P J (see *fig. 17.*). Take a strip of card-paper, A P B, about six inches long, and half an inch wide; attach narrow strips of tinfoil to the extremities of the card-paper, by means of insulating knobs of sealing-wax, and balance the card-paper, on a small indentation made at its centre, on the point, P, of a pin passed through a cork and placed on the top of a wine-glass, J. With the view of adjusting the balance, two small rings of indian-rubber are placed on the card, one on each side. This will form a delicate electroscope, which may be used in conducting some interesting experiments hereafter to be described.

Bring the strip of tinfoil, of this electroscope, near to the one extremity of the poker (see *fig. 17.*),

and then bring the insulated plate of the electroscope near to the other extremity, and the needle will be deflected; the tinfoil being electrified with positive electricity: touch the extremity *c* with the finger, then take away the plate of the electrophorus, and the needle of the electroscope will return to its first position; for the poker will be left in a negative state of electricity, while the tinfoil of the electroscope will be in a positive state, and so on to other experiments of this kind, illustrating the great law of electrical induction.

*A remarkable case of induction.*—Place a small tea-tray *T* upon a dry wine glass *J*, and upon this tray place the electroscope just described, as shown in *fig. 18.*; charge the tea-tray *T* with positive



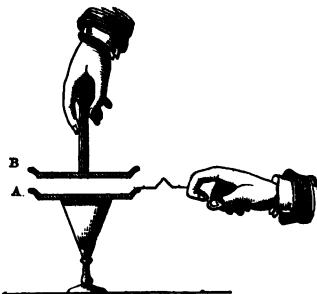
*Fig. 18*

electricity, by means of the electrophorus, described at page 20; then because the tin-foil *c B* is insulated, by the action of induction, the lower extremity *c* will be negative, while the upper extremity *B* is positive. Touch the upper extremity *B* of the tinfoil *c B*, and it will remain charged with negative electricity; now, bring the hand, over the tray, near to the extremity *c* of the tinfoil, and it

will be instantly repelled, giving the appearance of the hand as being negatively electrified, which, in fact, it really is from the induction of the tray T.

*To electrify a Tin Plate either negatively or positively, by means of the Electrophorus.*

(1.) Place the tin plate A upon a dry wine-glass (see *fig. 19.*); charge the plate B of the electrophorus positively, after the manner described at page 20., and bring it near to the insulated plate A (without allowing a spark to pass from the one to the other); touch the plate A, and a spark of *positive* electricity will be



*Fig. 19.*

received from the inductive action of the plate B; first take away the knuckle, and then take away the plate B, and the plate A will remain charged with *negative* electricity.

(2.) To electrify the insulated plate A positively; simply touch it with the charged plate B of the electrophorus.

*To exhibit the dancing balls.*—Put a few small pith balls into the plate A (see *fig. 19.*); bring the electrified plate B over them, as shown in the figure, and they will appear to jump up and down.

*The electric bell.*—Place a damp wine-glass C (as shown in *fig. 20.*), near to the insulated plate A; suspend a small brass ball, or button, D, from a dry silk thread, between the glass and the plate; electrify, time after time, the plate A,

by means of the electrophorus; and the ball D will oscillate between the plate and the glass, thereby producing a tingling sound.

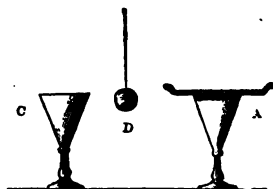


Fig. 20.

*The electrical pendulum.*—This instrument is represented in *fig. 21*.

A and B are two insulated plates; the one is charged with positive and the other with negative electricity: EF is a strip of card-paper, having a pin, P, passed through it, and

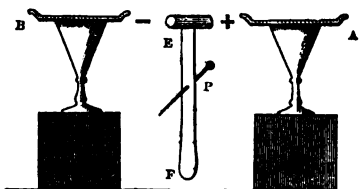


Fig. 21.

a piece of pith, E, attached to its upper extremity, by means of an insulating knob of sealing-wax; the pin P of the pendulum EF is supported on the edges of two wine-glasses, which are not shown in the cut. The apparatus is adjusted so as to allow the insulated pith E to oscillate between the edges of the plates A and B. With the view of causing the lower extremity F to preponderate, a small sliding ring of indian-rubber is placed on the portion PE of the pendulum.

*The electrical hammer.*—This simple piece of apparatus is represented in *fig. 22*. Here the pendulum EF of the apparatus just described, is sup-

ported in a horizontal position in the manner already described; the pith knob *E*, in this case, oscillates between the electrified plate *A* and a conductor *D*.

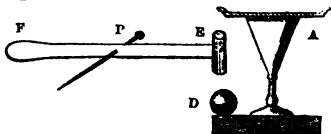


Fig. 22.

*Tate's electrical revolver.*—This simple and interesting piece of apparatus is represented in fig. 23. *F* and *E*

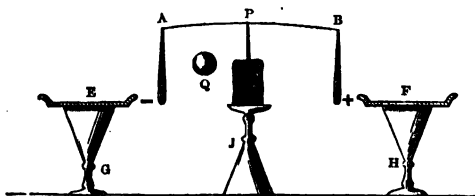


Fig. 23.

are two insulated plates charged with different kinds of electricity, (see p. 24.); *A B J* is the tinfoil electroscope, described at p. 22., placed between the electrified plates *E* and *F*, so that the lower extremities of the strips of tinfoil may nearly touch the plates *E* and *F*. When the plates are electrified, the electrical needle *A B* rapidly revolves upon its centre *P*; the plates charge the insulated strips of tinfoil as they pass them, so that the plates attract the strips of tinfoil, when they are on one side, and repel them when they are on the other side. The charge of the plates must be time after time renewed. The action of the instrument is improved by placing a conducting knob *Q* mid-way between the two plates *E* and *F*, so as to discharge the electricity of the strips, as they pass the conducting knob.

All the apparatus we have hitherto described may

be easily constructed at a very small cost, by any person of ordinary skill and patience. For various simple contrivances, and for fuller explanations of construction, the reader may consult the writer's work on "The Construction of Philosophical Apparatus."\*

\* "No. 1. On the Construction of certain new and simple Pieces of Electrical Apparatus." Longman and Co.

## ELECTRICAL MACHINES.

**ELECTRICAL** machines are used for generating electricity by friction on a large scale. They consist of three leading parts. The rubber is a soft hair **CUSHION**, covered with leather, or with some substance, which readily generates electricity by friction. The body on which the rubber acts, is either a **GLASS CYLINDER**, or a circular **GLASS PLATE**, which turns upon an axis. The receiver of the electricity is called the **PRIME CONDUCTOR**; it is a thin brass cylinder, or a brass rod, mounted on a glass pillar, or some insulating material. The action of an electrical machine is simply this: the glass cylinder, or the glass plate, as the case may be, upon being turned, rubs against the cushion, and thereby generates electricity upon the surface of the glass, which is continually carried round to the prime conductor.

## THE COMMON CYLINDRICAL MACHINE.

*Fig. 24.* represents an electrical machine of this kind. The glass cylinder **A B**, which rests on an axis passing through **C**, is made to revolve by means of the wheels **C** and **D** connected by a band, the wheel **D** being turned by means of the handle **R**; the cushion **H**, which rubs against the cylinder, is mounted on a glass pillar, **I**, which

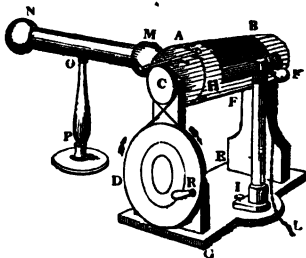
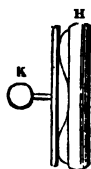


Fig. 24.

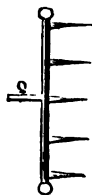
slides in a groove at the foot, for the purpose of adjusting the pressure upon the cylinder; the chain *K L* connects the cushion with the ground; a flap, *B*, of varnished silk, passes from the cushion over the cylinder, for the purpose of preventing the escape of the electricity into the air; the prime conductor *M N*, mounted on the glass pillar *O P*, has a row of points projecting from the extremity *M*, and coming nearly in contact with the surface of the glass cylinder. As glass is liable to collect moisture on its surface, it is usual to cover all the insulating pillars, as well as all those parts of the cylinder which do not touch the cushion, with a coating of varnish, which has a higher insulating property than glass.

*Fig. 25.* shows the construction of the cushion; where *H* is the rubber, with an adjusting spring fixed behind it, for keeping it continually pressed against the cylinder; *K* the brass knob, or ball, for attaching the chain.



*Fig. 25.*

*Fig. 26.* shows the form of the row of points attached to the prime conductor.



*Fig. 26.*

When the cylinder is turned round by the handle *K*; positive electricity is generated on the surface of the cylinder, and negative electricity on the cushion. The latter is carried off by the chain to the ground. The positive electricity is carried round to the points of the prime conductor, where it acts by induction on the natural electricity in the conductor, that is, by attracting the negative fluid and repelling the positive. The negative fluid, escaping by the points, unites with the positive fluid on the cylinder, and thereby

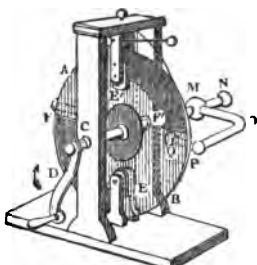
restores the surface of the cylinder to its natural state, so that when it arrives again at the rubber it is prepared for another charge of positive fluid ; at the same time the prime conductor is left charged with positive electricity. According to this theory, the negative electricity of the conductor is continually passing off by the chain attached to the cushion, which constantly keeps the conductor charged with positive electricity. By detaching the chain from the cushion, and placing it on the prime conductor, we are able to charge the cushion with negative electricity.

With the view of increasing the efficiency of the machine, the cushion is covered with an amalgam of zinc and tin. According to Singer, the best composition of the amalgam is two parts by weight of zinc, one of tin, and six of mercury. The mercury is added to the mixture of the zinc and tin, when in a fluid state, and the whole is then shaken in a wooden box, until it is cold ; it is then reduced to a powder, and mixed with a sufficient quantity of lard to reduce it to the consistency of paste. A thin coating of this paste is spread over the cushion ; but before this is done, all the parts of the machine should be carefully cleaned and warmed. Black spots and lines are readily taken from the glass, by applying a rag dipped in spirits of wine ; and the efficiency of the machine is greatly promoted by applying, with the hand, a piece of leather covered with amalgam to the cylinder.

#### THE COMMON PLATE MACHINE.

*Fig. 27.* represents a machine of this kind. A B is a circular plate of glass, turning on a horizontal axis C, by means of the winch or handle D ; the plate is embraced at E by two cushions, the pres-

sure of which is adjusted by screws; two similar cushions are placed at  $E'$ ; flaps, proceeding from the cushions, cover the glass at the spaces shown in the figure to about half an inch from the points on each side of the conductor; the conductor,  $POMF$ , is a small brass tube, or cylinder, bent so as to suit the



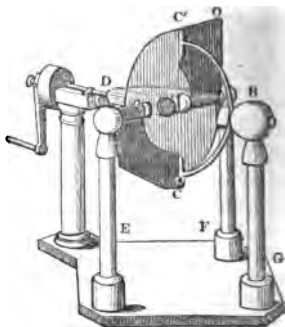
*Fig. 27.*

plate, and supported by a glass rod  $F'M$ , attached to the upright frame  $E$ ;  $PQ$ , running parallel to the surface of the plate, is that part of the conductor which carries the points, and a similar bent branch with points is formed at  $F$ . When the handle  $D$  is turned in the direction of the arrow, the cushions at the top, as well as those at the bottom, generate electricity; the points at  $F$  receive the electricity generated by the cushion  $E$ , whilst those at  $PQ$  receive the electricity generated by  $E'$ . In order to prevent the escape of electricity, all the extremities of the conductor are terminated in brass balls or globes. The principle on which this machine acts, is precisely the same as that of the common cylindrical machine. This machine, cost for cost, is more powerful than the cylindrical one, but the difficulty of insulating the rubbers, so as to obtain the negative fluid, is certainly an objection to it.

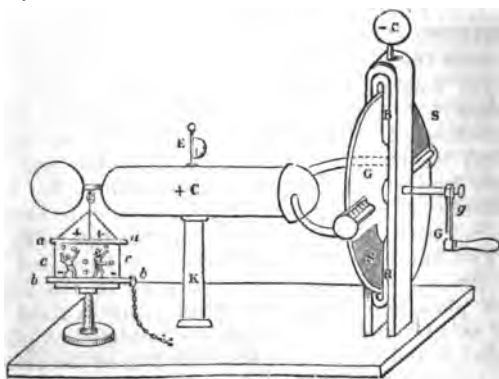
THE HAERLEM PLATE MACHINE, represented in *fig. 28.*, fully remedies this deficiency in the common plate machine. The glass plate is fixed to the axis  $D$ ; the two cushions are insulated on glass pillars,  $E$  and  $F$ ;  $CBG$  is the bent arm of the prime conductor, armed with points, and insulated on the glass pillar  $G$ ; in order to connect the cushion

with the ground, there is a bent or semicircular conductor, similar to  $CBC'$ , proceeding from the axis at  $D$ , and reaching to the balls of the two cushions.

When it is required to charge the conductor  $B$  with negative electricity, the semicircular rod  $CBC'$  is moved into a horizontal position, thereby bringing the points opposite to the two cushions, at the same time the other semicircular rod, on the opposite side of the plate, is moved round into a vertical position, thereby bringing its points at the top and bottom parts of the plate.



*Fig. 28.*

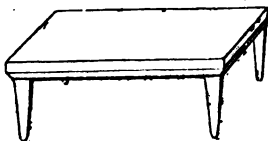


*Fig. 29.*

*Fig. 29.* represents another form of the plate machine; where *c* is the prime conductor, mounted on the glass pillar *K*; *G G* the glass plate; *g* the winch; *B B* the cushions; *s s'* the flaps, &c.; *E* a quadrant electrometer inserted in the conductor, to determine the quantity of electricity with which it may be discharged; and *a a, b b* an apparatus suspended from the conductor to illustrate the principle of electrical attraction and repulsion.

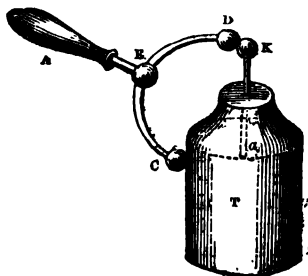
#### APPENDAGES TO ELECTRICAL MACHINES.

*The insulating stool*, represented in *fig. 30.*, consists of a board of hard, well-baked wood, supported on glass legs covered with varnish. It is useful for insulating any body charged with electricity; for instance, a person may stand upon the stool and become charged with electricity, upon being put in connection with the prime conductor of the electrical machine.



*Fig. 30.*

*Discharging-rods* are brass rods terminating with balls, or with points, fixed to glass handles. With these rods electricity may be taken from a conductor without allowing the electrical charge to pass through the body of the operator.

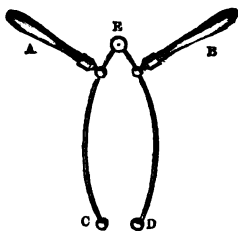


*Fig. 31.*

*Fig. 31.* represents a common discharger; where *A* is the glass handle, *c E D* the brass rod; *c* and *D* the balls.

*Fig. 32.* represents a double-handled jointed discharger; where *A* and *B* are the glass handles, *E* the joint, &c.

*The Leyden jar* consists of a glass cylinder, or wide-mouthed bottle *T* (see *fig. 31.*), both surfaces of which are coated with tin-foil up to about 3 inches of the top. The coating of tinfoil on the outside of the bottle is called the

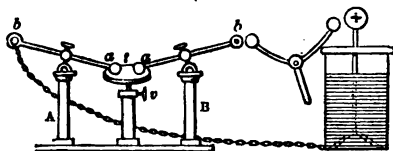


*Fig. 32.*

outer coating, the other on the inside is called the inner coating. Electricity is transmitted to this coating by means of a metal rod *K*, terminated at the upper extremity by a knob *K*, and at the lower extremity by a chain which comes into contact with the inner coating of the jar. The rod is fixed by passing tightly through a wooden plug, which fits firmly into the neck of the jar. Those portions of the glass which are not coated with the tinfoil are covered over with a thick coating of wax, to prevent a reunion between the electricity of the outer coating and that of the inner coating. When the jar is to be charged, it is held in the hand by the outer coating, and the knob *K* is brought near to the conductor of the electrical machine. While spark after spark of positive electricity enters the jar, the positive electricity, on the principle of induction, is driven off from the outer coating, so that while the inner coating becomes charged with positive electricity, the outer coating becomes charged with negative electricity in a manner which will be hereafter more fully explained. When the jar is to be discharged, the operator, holding the discharging rod by the glass handle *A*, brings one

knob *c* in contact with the outer coating, and then gradually brings the other knob *D* near to the knob *K* of the jar; the reunion of the two fluids (the positive from the inner coating and the negative from the outer coating) takes place between the two knobs *D* and *K*, with a bright spark and a snapping noise.

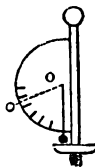
The universal discharger, represented in *fig. 33.*, consists of a dry deal, on which two glass pillars,



*Fig. 33.*

*A* and *B*, are fixed; two brass rods, *a b* and *a b*, capable of turning, on a ball and socket joint, in any direction, and also capable of sliding in the top balls; the knobs *a a* are applied to a wooden table *t*, which admits of being raised or depressed, by means of an adjusting screw *v*; a narrow strip of ivory is inlaid across the table; the knobs *a a* may be screwed off, and replaced by points, or by forceps. This piece of apparatus is much used for passing strong charges of electricity through any substance.

The quadrant electrometer.—This instrument is used for indicating the quantity of electricity accumulated in the prime conductor of the machine. It consists of a vertical stem or rod, which admits of being inserted in a hole made in the prime conductor; to the side of this stem is fixed a graduated quadrant, carrying a light needle or rod,



*Fig. 34*

terminated by a pith ball; this light needle turns on a pivot, o, fixed in the centre of the quadrant. When the machine is not in action, the light needle hangs parallel to the vertical stem, but when the machine is worked the needle is repelled from the stem, and the height to which it ascends indicates the amount of electricity accumulated in the prime conductor.

**A FEW EASY EXPERIMENTS WITH THE ELECTRICAL MACHINE.**

*Exp. 1.* Work the machine; bring your knuckle near to the prime conductor; a vivid and instantaneous flash, accompanied with a snapping noise, passes between the conductor and your hand, which produces a slightly painful sensation:—this is the electric spark.

A spark will be communicated to any conductor. Hold a stick of sealing-wax, or any other non-conductor, to the prime conductor; no spark will be received.

*Exp. 2.* Fix the quadrant electrometer on the prime conductor; work the machine, and observe to what height the pith ball is repelled. Hold the point of a sewing needle near to the conductor; observe! the pith ball of the electroscope instantly falls. Take sparks from the conductor; observe! the pith ball falls at the instant each spark is taken.

*Exp. 3.* Let a boy stand on the insulating stool, and let him place one of his hands on the prime conductor; work the machine; take sparks from his body: see! how he winces from the smarting sensation they produce, especially when taken through his clothes. See *fig. 35*.

*Exp. 4.* Charge a Leyden jar fully, and discharge it with the jointed discharging rod: see! what a vivid spark it gives.

Charge the Leyden jar (with about half a dozen sparks); grasp the outer coating with one hand, and touch the knob with the other. The



*Fig. 35.*

electric fluid, in passing through your body, gives you what is called an **ELECTRIC SHOCK**.

Let a few boys form a ring by taking hold of each other's hands; let the first boy in the ring grasp the outer coating of the charged jar, and let the last boy touch the knob; instantaneously all the boys in the ring will receive a shock.

## ELECTRICAL ATTRACTION AND REPULSION.

THIS subject has been fully explained, in the preliminary portion of this work, in relation to a numerous class of simple experimental facts. But the electrical machine enables us to exhibit the various phenomena of electrical attraction and repulsion in the most striking manner.

*Exp. 1. Repulsion of electrified threads.*—Take a skein of linen threads, and, after tying them together at each end, suspend them from the prime conductor of the machine. When the handle of the machine is turned the threads will become electrified, and will repel each other, so that they will swell out in the middle, forming a figure resembling the meridian lines on a globe.

*Exp. 2. The frightened head of hair.*—Fix a doll's head of hair in the prime conductor; work the machine, and the hairs will appear to stand on end, from their mutual repulsion, presenting an exaggerated appearance of a person in a state of fright.

Present a pointed rod to the hairs and they will immediately collapse.

A bunch of large downy feathers, inserted into the hole of the prime conductor, will present a similar appearance.

*Exp. 3. The electrical dance.*—In this experiment, a metal plate is suspended, by a chain, from the prime conductor; a few inches below this plate, another plate is placed in connection with the earth; and some light figures are placed upon the bottom plate, as

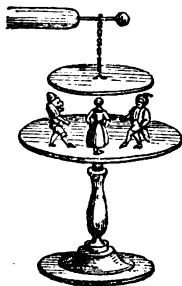
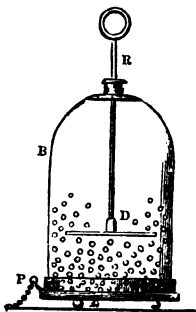


Fig. 36.

shown in *fig. 36*. When the machine is worked, the figures appear to dance, or to jump up and down, from the one plate to the other, in a very grotesque manner.

*Exp. 4. The dancing balls.*—Here a number of cork or pith balls are placed upon a metal disc *P*, communicating with the ground, and the whole of them are covered with the glass bell *B*, whose upper part is open, and provided with a collar of leather, through which a rod *RD* passes, carrying at its lower extremity a metal disc *D*. By this construction, the upper disc *D* can be placed at any convenient distance from the lower disc *P*. The ring *R* of the rod is put in communication with the prime conductor, so that when the machine is worked, the balls are attracted by the plate *D*, and then repelled from it, being charged with positive electricity; now when they touch the bottom plate *P*, the electricity is taken from them, and they are thus prepared to be again attracted by the plate *D*, and so on.



*Fig. 37.*

We may make this experiment in a more simple manner by using a glass tumbler, whose interior surface has been electrified by touching its different parts with the pointed extremity of a metal rod fixed in the conductor of an electrical machine in action. The glass is then inverted upon a table, over a lot of pith balls;

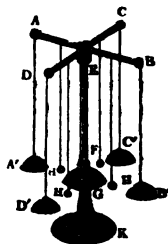


*Fig. 38.*

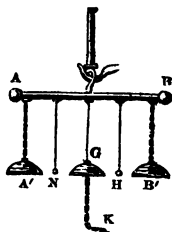
the balls immediately begin to dance, being alternately attracted and repelled by the electric fluid on the interior surface of the glass, as shown in *fig. 38*.

*Exp. 5. The electrical bells.* — The alternate attraction and repulsion of electrified bodies is beautifully illustrated in this piece of apparatus, which is of some importance, inasmuch as it is frequently employed in tropical countries to detect the presence of an electrified cloud. A glass pillar supports two metal rods, *A B* and *C D*, from which four bells, *A' B' C' D'*, are suspended by chains. A central bell *G*, at the foot of the glass pillar *E F*, is placed on the wooden stand *K*; a chain, *G K*, connects this bell with the ground. From the extremities of the rods *A B* and *C D*, four small brass balls, *H H*, are suspended by silken threads. When the machine is in action, the cross rods are put in connection with the prime conductor, and the four bells *A' B' C' D'* become charged with electricity, and consequently attract and repel the insulated balls *H H*. When the balls *H H* are repelled they strike the bell *G*, to which they give up the electricity they received from the electrified bells, and this electricity is carried off by the chain *G K*. The tingling noise thus produced will continue so long as electricity is supplied to the bells *A' B' C' D'*.

*Fig. 40.* represents a simpler apparatus of this kind, where the bells are hung from a brass rod



*Fig. 39.*

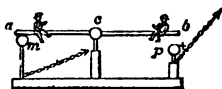


*Fig. 40.*

A B, which may be suspended from the prime conductor. In this form of the apparatus the central bell is suspended by a silken thread, and is connected with the ground by means of the chain G K.

*Exp. 6. The electrical seesaw.*—This consists of a small strip of wood (see *fig. 41.*), about a foot long, covered with tinfoil, and insulated on *c* like a balance.

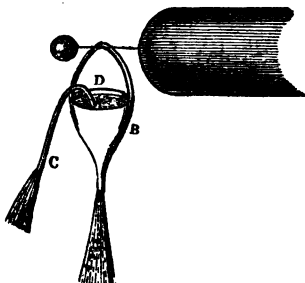
A slight preponderance is given to it on the side *a*, where it rests on a metal ball *m*, at the top of a brass wire; *p* is an insulated metal ball. The ball *p* is connected with the interior coating of an electrical jar, while *m* is connected with its exterior coating. When the jar is charged, the seesaw motion will immediately be produced. The cause of this motion depends upon the common principle of electric attraction and repulsion.



*Fig. 41.*

This experiment will succeed quite as well by simply connecting the ball *p* with the prime conductor of the machine, and the ball *m* with the ground.

*Exp. 7. The electrified water.*—Here a little metal bucket, B, having a small hole in its bottom, is suspended from the prime conductor of the electrical machine. The hole in the bucket is so small that the water merely falls from it in drops when the machine is not in action; but when the machine is worked



*Fig. 42.*

the water runs from the hole in a continuous stream, owing to the repulsion which takes place amongst the particles of the electrified water.

The same experiment may be performed by inserting a siphon, D C, having a small bore, into the water, as shown in *fig. 42*.

A similar effect would be produced by suspending a sponge, saturated with water, from the prime conductor of the machine.

*Exp. 8. Electrified sealing-wax.*—Ignite the extremity of a stick of sealing-wax, and when it is in a full state of fusion, blow out the flame and bring the melted wax near to the prime conductor of the machine; numerous fine filaments of wax will fly to the conductor, and will adhere to it, forming upon it a sort of network like wool. This is a simple case of electrical attraction. The experiment will succeed best if a small piece of wax is attached to the end of a metal rod.

*Exp. 9. The electrical swing* consists of a light figure placed upon a swing, formed by a silk thread. The light figure swings between two balls, one of which is insulated and put in connection with the prime conductor, the other ball being put in connection with the ground. The principle of this apparatus is the same as that of the electrical seesaw.

*Exp. 10. The electrical swan.*—In this experiment a light piece of cork, or any other light substance, cut in the shape of a swan, is made to float in a basin of water placed upon the insulated stool. The water is electrified by means of a chain which passes from it to the prime conductor. The little floating swan will approach any non-electrified substance that may be presented to it.

In making this experiment, the cork should be first completely immersed in water, to render it a conductor of electricity.

*Exp. 11. The electrical spider.*—An electrical jar *L* has a ball *b* connected with its exterior coating. When the jar is charged with the positive electricity of the prime conductor, any light substance, such as a representation of a spider, suspended between the knobs *a* and *b*, will oscillate between them.

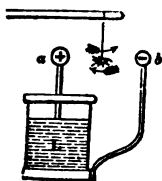


Fig. 43.

## LUMINOUS EFFECTS OF ELECTRICITY.

## THE ELECTRIC SPARK.

WHEN the knuckle, or a brass ball at the end of a rod, is presented to the conductor of a machine in full action, a spark is produced by the passage of



Fig. 44.

the fluid from the conductor to the knuckle. The spark has a zig-zag form, similar to a flash of forked lightning. The length and intensity of the spark depends upon the power of the machine. Sparks may be taken from the prime conductor of a very powerful machine, at the distance of twenty or thirty inches. When the continuity of a conducting substance, such as tinfoil, is broken at different parts, a spark will be produced at every place where the course of the conductor is broken. A great variety of beautiful experiments may be made to illustrate this principle. These experiments should be made in the dark.

*Exp. 1. Luminous spangles.*—Sew a number of tinfoil spangles on silk ribbon, about a quarter of an inch apart; hold the ribbon by one extremity, and bring the other near to the prime conductor; the electricity, in its passage from spangle to spangle, will form a beautiful line of light.

*Exp. 2. The spiral tube.*—This consists of two glass tubes, about a foot long, one of which is first & within the other. The inner tube has conduct<sup>s</sup> of tinfoil pasted on its outside surface

the form of a spiral. The two ends of the tubes are mounted with brass caps. Hold the tube by one of the brass

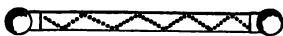


Fig. 45.

caps, apply the other cap to the prime conductor ; a beautiful spiral stream of electric light will pass from one end of the tube to the other.

A spiral tube made to revolve within an electrified hoop, produces a splendid effect.

Spangles of tinfoil may be pasted on common window glass so as to produce various luminous devices, such as geometrical figures, or short words.

*Exp. 3. Ignition of spirits of wine.*—Let a person, standing on the insulating stool (see fig. 35.), lay one hand on the prime conductor, and with the other hand let him hold a warm teaspoon containing spirits of wine ; let some other person present his knuckle to the spoon, and the passage of the spark will cause the spirits to ignite.

*Exp. 4. Ignition of æther on water.*—Pour some water into a wine-glass, whose outer surface is perfectly dry ; pour some æther on the top of the water and connect the water, by means of a chain, with the prime conductor of the machine. Turn the handle of the machine, and present your knuckle, or a metallic ball, to the surface of the æther, and the electric spark will ignite the æther.

*Exp. 5. The electrical pistol.*—The electric spark will readily cause a mixture of hydrogen and common air to explode. The electrical pistol, represented by fig. 46., is commonly employed for this purpose ; *a* is a brass tube or barrel, open at one end ; *b* is a copper wire, insulated by its being inserted in an ivory tube, which passes through one side of

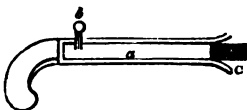


Fig. 46.

the barrel, and nearly touches the inner surface of the opposite side. Hold the mouth of the pistol over a stream of hydrogen gas, proceeding from a pipe; after a sufficient quantity of gas has entered, close the mouth of the pistol with a cork *c*; take a spark through the knob *b*, and the cork will be discharged with a loud report, from the explosion of the gas by the passage of the spark from the extremity of the wire to the inner surface of the barrel. In order to avoid any accident, the cork should be attached to the pistol by a loose string.

*Exp. 6. Ignition of common gas.*—Let a person, standing on the insulated stool, touch the prime conductor with one hand, and with the knuckle of the fore-finger of the other hand let him transmit a spark to the orifice of a gaspipe from which a current of gas is being discharged; and the gas will be ignited.

Bring a candle with a long snuff, that has just been extinguished, near to the prime conductor, so that the spark passes from the conductor, through the smoke, to the candle; it is relighted.

#### DIFFERENT FORMS OF THE ELECTRIC LIGHT.

The intensity of the electric light depends, not only upon the density of the accumulated electricity, but also upon the density and nature of the gas through which the spark passes. Thus the spark is bright and short when it passes through dense air, but when it passes through rarified air it is long and diffused, and of a violet hue. The colour of the spark is also much influenced by the composition of the gas through which it is transmitted, as well as by the nature and form of the conductor. In this way, a great variety of surprising and beautiful luminous experiments may be performed.

*Exp. 1. The electric light from points.*—Place

a pointed rod in the prime conductor charged with positive electricity, and the electric light will issue from the point in the form of a brush. Try to take a spark from the conductor, when the pointed rod is attached to it.



Fig. 47.

Hold the point of the rod towards the prime conductor, and a *star* will be seen on the point.

Attach the pointed rod to the insulated cushion, charged in this case with negative electricity, and the electric light will be seen in the form of a star.

Insulate the cushion as well as the prime conductor, and attach pointed rods to each of them, so that the points may be at the distance of four or five inches from each other; then, upon working the machine, a brush will be seen upon the point attached to the prime conductor, while a star will be seen upon the other point, presenting the appearance as if the conductor gave out its electricity, while the cushion received it. These phenomena were at one time considered as strong arguments in favour of Franklin's theory of electricity.

*Exp. 2. Passage of the electric light through rarefied air.*—Fix a wire, terminated by a brass ball, to the plate, P, of an air pump; attach a similar ball (by a sliding wire A B) to the top of the receiver R, so as to bring the one ball over the other, and at the distance of about one inch apart. Connect the outer ball B with the prime conductor, and the bottom plate P

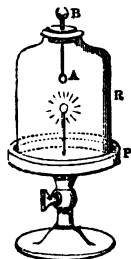


Fig. 48.


with the insulated cushion. Upon turning the handle of the machine, a continuous stream of electric light will pass from the positive to the negative ball. While no light is exhibited by the positive ball, a beautiful luminous atmosphere entirely surrounds the negative ball, giving the appearance of a fluid in the act of passing out of the one ball and entering into the other. By altering the distance of the balls from each other, different aspects may be given to the electrical light.

*Exp. 3. The electrical aurora borealis.*—Instead of the receiver R of the last experiment, let a glass tube, about twenty inches long and three inches in diameter, be used; and instead of the two discharging balls, let two points be substituted. When the tube is exhausted of air, and the machine is worked in the dark, the whole length of the tube will be one sheet of violet red light; if a small portion of air be admitted, numerous flashes will issue from the points and traverse the tube; when a little more is admitted, these flashes will appear to glide in a serpentine manner down the interior of the tube. The succession of luminous phenomena, in fact, bears a striking resemblance to the aurora borealis.

An *aurora flask*, sold by instrument makers, answers very well for exhibiting these phenomena.

*Exp. 4.* The electric spark is blue when transmitted through nitrogen.

*Exp. 5. Passage of the electric light through the Torricellian vacuum.*—Seal a short wire within one end of a glass tube about 32 inches long; attach a brass ball to the external end of the wire; fill a dry tube with mercury, and invert it in a cup of mercury; a vacuum will be formed in the upper part of the tube; connect the ball with the prime conductor; turn the machine, and a current of violet-coloured light will pass through the vacuum.



## MECHANICAL EFFECTS OF ELECTRICAL POINTS.

WHEN the electric fluid discharges itself from a pointed conductor, a *reaction* or *recoil* is produced, which may be used to give motion to certain delicate pieces of mechanism, in the same way as fluids are employed in the common reaction machines.

*Exp. 1. The electrical wind.*—Fix a pointed rod on the prime conductor; work the machine; bring the back of your hand near to the point, and you will distinctly feel the electrical wind proceeding from the point.

Bring the flame of a candle near to the point; the flame will be extinguished by the electrical wind, chiefly caused by the repulsion of the electrified air from the point.

*Exp. 2. The electrical fly-wheel.*—A metal cross turns on a pivot which is fixed on the prime conductor; the points of this cross are all bent in the same direction; when the machine is turned the fly revolves in the directions of the arrows, shown in the figure, that is, contrary to the direction in which the points are bent.

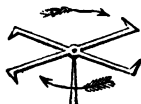


Fig. 49.

The fly is sometimes mounted on an insulated stand, as shown in *fig. 50*.

*Exp. 3. The electrical orrery.*—This instructive and elegant piece of apparatus is represented by *fig. 51*; where *s* represents the sun, *E* the earth, and *M* the moon. The earth and the moon turn upon the pivot *B*, and the sun, with the earth and the moon



Fig. 50.

turn upon the pivot A, which is placed in their common centre of gravity. The point AC is fixed on the prime conductor. The points *a* and

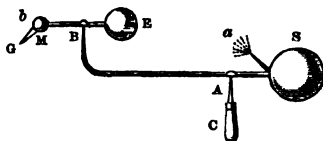


Fig. 51.

G are so placed that all the pieces revolve in the same direction, that is, from west to east.

*Exp. 4. The electrical inclined plane.*—Here the recoil of the electrical discharge from the points causes the fly to roll up an inclined plane formed by two wires, A B and C D, supported by insulating pillars. One of the wires is connected with the prime conductor by means of the chain C K.

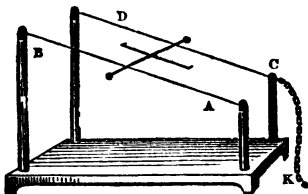


Fig. 52.

*Exp. 5. Repulsion of a point.*—Bring an insulated point, connected with the prime conductor, near to the electrical swan (see *exp. 10. p. 42.*), then, instead of being attracted, it will be repelled. This is caused by the repulsion of the electrified air from the point.

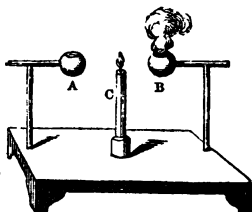
On this principle a light paper wheel may be made to revolve upon a pointed conductor being presented to its sails.

The following remarkable experiment depends upon the same principle :

Pieces of phosphorus are put into the two metal cups A and B insulated on glass pillars ; a candle, C, is placed exactly between them ; the cup A is connected with the prime conductor, and the cup B with

the insulated cushion; when the machine is worked, the electric wind, blowing from the positive cup A to the negative cup B, causes the flame to fly towards the cup B, and to heat it, so as to ignite the phosphorus.

This experiment was at one time thought to be a decided argument in favour of the single fluid theory; but the phenomenon may be satisfactorily explained upon the theory of two distinct fluids.



*Fig. 53.*

## PECULIAR APPLICATIONS OF THE PRINCIPLE OF INDUCTION.

THE principle of induction has already been explained, but the following experiment, made with the electrical machine, will render it more apparent.

*Exp. 1.* Take an insulated metal cylinder B, and attach small pith balls, suspended from cotton threads, to different parts of its surface; gradually bring an

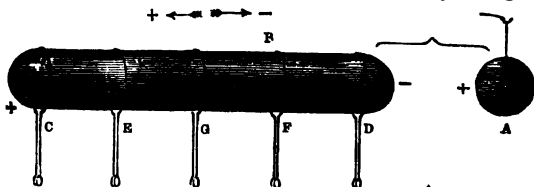


Fig. 54.

electrified body A, which has been charged with the prime conductor, near to this cylinder; when A is about an inch from the conductor, no spark having passed from A to B, the pith balls at the extremities C and D diverge; at E and F the divergence is less than it is at C and D; and at or near the centre G the balls do not diverge at all.

As we have already explained, the positive fluid is driven to the extremity C, and the negative fluid is drawn to the extremity D.

When A is withdrawn, all the balls fall back to their natural position, and the positive and negative fluids, on the conductor B, reunite and return to their natural state,—all electricity disappears.

Before withdrawing A, touch the extremity C, so as to take away the positive fluid; the conductor will remain charged with negative electricity, and so on, as described in the experiments given at p. 23.

Electricity may be induced by induction in a

series of insulated conductors, placed in a line, with their extremities in order near to each other.

#### THE ELECTROPHORUS.

The electrophorus, invented by Volta, depends upon the principle of induction; it is capable of retaining for a considerable time the electricity developed upon its non-conducting surface by friction. It is composed of a cake of resin poured into a circular metal mould, or

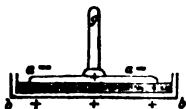


Fig. 55.

plate, *bb*; of a disc of metal *a a*, a little less than the cake, furnished with an insulating handle *g*. The cake of resin is electrified negatively by rubbing its surface with a cat's skin; the metal disk is then placed upon the excited cake; we then touch the plate with the finger, which gives us a spark of negative electricity, and raise it by the handle *g*, when it will be found charged with positive electricity; upon touching the plate we receive a spark of positive electricity.

When we first touch the metal plate (while in contact with the resin) the negative electricity is taken away from it, owing to the repulsion of the negative fluid of the cake; now when the plate is raised by the insulating handle, it is charged with positive electricity, because the negative fluid had been taken away from it, while the positive fluid in it remained by the attraction of the negative fluid of the cake.

As the cake will retain its electricity for a very long time, any number of sparks may be taken from it with scarcely any diminution of intensity.

The experiments given in connection with *fig.* 19. *Fig.* 24., may be explained on the same principle as the electrophorus.

The following improvements of the electrophorus were first published in the Author's little work on the Construction of Philosophical Apparatus.

#### TATE'S ELECTROPHORIC MACHINES.

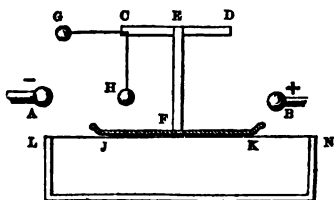
The intensity of the electricity transmitted to the conductor by the electrophorus, described at page 20., depends upon the following circumstances: (1) The size of the plate; (2) the completeness of the contact of the plate; (3) the rapidity with which the strokes are performed.

The following contrivances will give power to the instrument, by facilitating the operation, and by lessening the time required for performing each stroke.

#### DOUBLE-ACTING ELECTROPHORUS, OR AN ELECTROPHORUS CAPABLE OF PRODUCING BOTH KINDS OF ELECTRICITY.

This simple contrivance is represented in *fig.*

56. L Q N is an open box; L N sheet gutta-percha stretched tight over its top; J K the plate of the electrophorus; E F a strip of double gutta-percha, attached to the plate



*Fig. 56.*

for the purpose of lifting it, forming a loop at the top for receiving an insulating rod D C, which may be a rod of glass, or a stick of sealing-wax; G O H a bent insulated wire, terminated with knobs, G and H; A an insulated conductor, for receiving the negative electricity; B another insulated conductor, for receiving the positive electricity; these

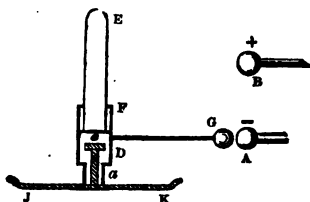
conductors are placed at the distance of six or eight inches from the plate *JK*, and the length of the wire *CH* is such as to allow the knob *H* to come into contact with the plate *JK* at the same time as the knob *G* comes into contact with the conductor *A*. The machine is worked in the following manner:—

Rub the surface of the gutta-percha with a piece of fur, or rabbit's skin; place the plate *JK* upon the excited sheet, taking care to hold it by the insulating handle *CD*; depress the handle *CD*, until the knob *H* comes in contact with the plate *JK*; then a spark of negative electricity will be transmitted to the conductor *A*; raise the plate *JK*, by means of the insulated handle, until it strikes the conductor *B*; then a spark of positive electricity will be transmitted to the conductor; and so on to an almost indefinite number of times. The action of the machine simply consists in raising and depressing the hand.

It will be observed, that, at each upward stroke, the knob *G* is raised from the conductor *A* before the plate *JK* is lifted off the gutta-percha.

The conductors *A* and *B* may be used in the same way as the conductors of an ordinary electrical machine, that is for charging jars, &c.

*Fig. 57.* represents another form of this machine, which possesses some advantages over that just described. *JK* represents the plate; *A* and *B* the conductors, already described; *EF* an insulating handle, of sealing-wax, or glass covered with seal-



*Fig. 57.*

ing-wax, cemented into a metal tube *F D*, which is fixed to a smaller tube *a*, coming in contact, time after time, with the plate *J K*; this tube *a* works smoothly on a brass rod *e*, fixed to the plate *J K*, having a stop, or small rim, at its top, for the purpose of stopping the ascent of the small tube *a*; *F G* is a wire fixed to the tube *F D*, and terminated by a knob *G*. By this contrivance the rod *F G* admits of an up and down motion upon the pin *e*, at the same time that the plate *J K* admits of being lifted off the gutta-percha. The machine is worked in the following manner:—

Hold the plate by the handle *E*, and place it upon the excited gutta-percha *L N* (see *fig. 56.*); depress the handle *E*, until the knob *G* comes into contact with the conductor *A*, and a spark of negative electricity will be transmitted to it; raise the handle until the knob *G* comes into contact with the conductor *B*, and a spark of positive electricity will be transmitted to it; and so on, as before described.

#### SINGLE-ACTING ELECTROPHORUS.

The plates, with their peculiar appurtenances, just described, may be employed with great advantage in the place of the simple insulated plate, described at page 20. The contrivances connected with these plates, enable the operator to perform each stroke more rapidly, leaving, at the same time, his left hand free to be used in any matter requiring his attention. All that is required in the application of these plates to the common sheet-electrophorus, is simply to have a conductor placed so as to come in contact with the knob *G* at the moment the plate *J K* falls upon the excited gutta-percha.

## DISGUISED ELECTRICITY.—CONDENSERS.

If a conductor connected with the ground be brought near to one extremity of another conductor charged with electricity, then the quantity of the electric fluid at that extremity will be considerably increased. This fact is just what we should have anticipated from the peculiar properties of the electric fluid.

Let  $AB$  be an insulated plate charged with electricity (say with  $+$  electricity);  $A'B'$  another plate, connected with the ground by means of the chain  $F'G'$ . Connect  $AB$  with the prime conductor, by means of the jointed discharger  $GHEF$ ; remove the jointed discharger, then  $AB$  will become charged with positive

electricity, which will have the same intensity as that of the prime conductor; bring the plate  $A'B'$  near to the charged plate  $AB$ , then the electricity on its surface will be considerably increased. For whilst the positive electricity of  $AB$  repels the positive electricity of

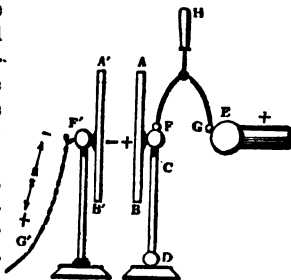


Fig. 58.

$A'B'$ , at the same time it attracts its negative electricity; but this negative fluid accumulated on the plate  $A'B'$ , in its turn reacts upon the plate  $AB$ , by attracting more of the positive fluid in it towards the surface nearest to the plate  $A'B'$ ; this increase of fluid on the plate  $AB$  produces a further action upon the plate  $A'B'$ , and so on to an indefinite series of actions and reactions. The negative fluid accumulated in  $A'B'$  is called DISGUISED electricity, for

it cannot be detected by any ordinary means; it is retained or held there entirely by the attraction of the positive fluid in A B. The plate A' B' is called the *condensing plate*, and A B the *collecting plate*. An instrument constructed on this principle is called *the condenser*.

This principle of disguised electricity may be readily established by experiment.

*Exp. 1.* Let the charged plate A B be connected by a chain with the insulated balls F, and the insulated plate A' B' with the insulated balls F'. First charge the plate A B (say with positive electricity), then the balls F will diverge; bring the plate A' B' near to A B, then the electricity in A' B' will be decomposed, and the balls will diverge. Touch A' B' with the finger so as to carry away its positive electricity set free, then the balls F' will immediately cease to diverge, and the

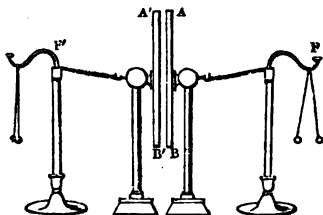


Fig. 59.

balls F will have now only a very feeble divergence. The negative electricity in A' B' exists in a DISGUISED state. Withdraw A B and A' B' from each other, taking care not to touch them, then immediately the balls diverge,—those at F with positive electricity, and those at F' with negative. Bring the plates again near to each other, and the divergence of the balls F' again ceases, and that of F diminishes. The negative fluid of the plate A' B' is again disguised, and the positive fluid is partly withdrawn from the extremity F towards the extremity A B, by the attraction of the negative fluid in the plate A' B'.

These facts enable us to give a satisfactory explanation of the principle of the condenser, of the electroscope, and of the Leyden jar.

#### THE CONDENSER.

The condenser, the principle of which has just been explained, is used to detect the presence of electricity where it is so very small as to require it to be collected and condensed before it will affect the electroscope. It consists of two discs of metal, *b b* and *c c*, whose touching surfaces are polished and covered over with a thin coat of varnish or some non-conducting substance; the upper plate is the collector and the lower one the condenser; the condenser stands on an insulating glass pillar *n*, and the collector

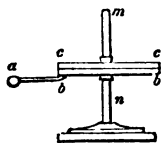


Fig. 60.

has an insulating handle *m* attached to it, by which it may be lifted; a brass wire *a b*, with a knob *a*, is fixed to the under side of the condensing plate, for the purpose of connecting it with the ground.

The apparatus is thus used:—Place the body whose electricity is to be examined in connection with the collector *c c*; touch the ball *a* with the finger, and after having taken it away, suddenly raise the collector by the glass handle *m*, and the electricity of the body under examination will have accumulated itself in the collector, and the opposite fluid will be found in the condenser; present the collector to any delicate electroscope or electrometer, and the accumulated electricity will be rendered apparent. The *rationale* of this process has already been explained.

The author has described, in his little work on

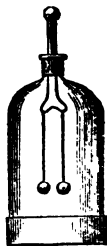
philosophical apparatus, various pieces of apparatus for demonstrating the principle of disguised electricity, as well as that of the condenser.

#### ELECTROSCOPES AND ELECTROMETERS.

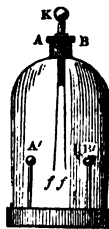
There are a great variety of electroscopes. For all ordinary purposes, the pith-ball electroscope, represented in *fig. 3.*, or that described at page 12., is quite sufficient. But in pursuing many electrical inquiries, we require instruments of more delicacy, or of more durability.

In order to render electroscopic instruments more sensitive and more accurate, the two light bodies are suspended from a metal rod and enclosed in a glass bell; and the extremity of the rod (which is either a knob or a plate) is to be touched with the electrified substance. The light bodies, thus suspended, are either pith balls, as shown in *fig. 61.*, or two gold leaves, as in Bennet's electrometer, or THE GOLD LEAF ELECTROMETER, shown in *figs. 62.* and *63.* In *fig. 62.* two knobs, *A'* and *B'*, are placed on each side of the gold leaves *f f*, so that when the leaves diverge too strongly, they impinge upon the knobs, and are thus discharged of their electricity; this contrivance prevents the leaves from being torn by adhering to the sides of the glass bell.

In order to insulate the electricity given to the cap or plate *K*, the metal rod carrying the gold leaves passes through a glass tube, which is ce-



*Fig. 61.*



*Fig. 62.*

mented to a ferrule on the plate A B, closing the top of the glass cover (see *fig. 63.*). This plate is screwed upon the glass cover, so that the leaves may be placed within the glass without injuring them. The gold leaves are attached to the lower extremity of the metal rod, simply by the adhesion of gum. Before using any electrometer it is important that all its parts be perfectly dry, and that the surrounding air be warm and free from moisture.



Fig. 63.

To use the gold leaf electrometer: Bring an excited glass tube near to the cap K, and the gold leaves will diverge with positive electricity, because the positive fluid of the glass drives the positive fluid of the cap into the gold leaves. Excited sealing-wax brought near to the cap will cause the leaves to collapse.

The following is the best method of using the simple gold leaf electrometer represented in *figs. 62. and 63.*: for it causes the gold leaves to be *permanently divergent*. Electrify a stick of sealing-wax; hold the electrified wax very *near* to the cap K, without touching it; the gold leaves will diverge from each other on the principle of induction, with the same electricity as the wax, that is, with negative electricity; touch the cap with the finger, and the gold leaves instantly collapse; *first* remove the finger, *then* the electrified body and the gold leaves will remain *permanently* divergent, with an electricity opposite to that of the wax, that is, with positive electricity. Now bring an electrified glass tube near to the cap K, and the divergence of the leaves will be increased, because the glass, being positive, will drive more of the positive fluid into the gold leaves. After taking the glass rod away,

bring electrified brown paper near the cap of the electroscope; the divergence of the gold leaves will be decreased, because the brown paper, being negative, will drive the negative fluid into the gold leaves, thereby neutralising the positive fluid at first in them.

It should be observed that where the charge of the leaves is *temporary*, the electricity is the same as the excited body; but where the charge is *permanent*, as in the preceding case, the electricity is of an opposite kind

*Experiments with the Gold-leaf Electroscope.*

*Exp. 1.* Strike the cap of the electroscope with a warm silk handkerchief; the leaves will diverge with negative electricity. Verify this by bringing an excited stick of sealing-wax near to the cap.

*Exp. 2.* Excite a silk ribbon, bring it near to the cap of the electroscope; the leaves instantly diverge: excite a glass rod; bring it also near to the cap; the divergence of the leaves is diminished, thereby showing that the electricity of silk is negative.

*Exp. 3.* Rub a roll of brimstone with a piece of warm flannel, hold the excited brimstone near to the cap of the electroscope, touch the cap with the finger; *first* take away the finger, and *then* the brimstone; the gold leaves will remain *permanently* divergent with positive electricity. Verify this by bringing an excited stick of sealing-wax near to the cap.

*Exp. 4.* Place a tin vessel containing water on the cap of the electroscope (see *fig. 63.*); drop a red-hot cinder into the water; the leaves will instantly diverge. Here the escape of steam generates electricity.

*The gold-leaf condensing electroscope, represented*



in *fig. 64.*, simply consists in the application of the condenser described at page 50. to the gold-leaf electroscope. Here *cc'* is the collecting-plate, with its glass handle *m*, placed upon the plate of the electroscope. In order to render this instrument more delicate, the glass-bell of the ordinary electroscope is enclosed by a glass case, into which some chloride of calcium is put, with the view of absorbing any moisture which may be in the circumjacent air.

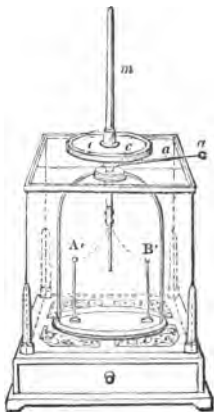


Fig. 64.

The degree of divergence of the gold leaves only gives us a rude idea of the intensity of the electricity with which an excited body is charged; for the divergence is not exactly in proportion to the intensity of the charge. These instruments, therefore, should be called *electroscopes* rather than *electrometers*. The name of electrometer should only be given to such instruments as Coulomb's balance, which afford us the means of exactly comparing the electrical intensities of any two bodies.

*The needle electrometer*, represented in *fig. 65.*, is a rod or needle balanced on a point, having pith balls fixed to its extremities.

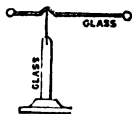


Fig. 65.

*Coulomb's torsion electrometer.* — For ordinary purposes, the instrument represented in *fig. 66.* will be found exceedingly useful. A small disc of gil

paper C, is attached to the end of a needle of gum-lac or sealing-wax; the needle is suspended by a thread of sealing-wax K D, after the manner described at page 13., and placed within a glass jar or bottle, as shown in the figure; passing through the side of the jar, and on a level with the needle, is a brass wire terminated with gilt balls A and B. To use the instrument, turn the knob K, if necessary, so as to bring the disc C in contact with the ball B; touch the ball A with the electrified body; then C, being electrified in the same way as B, will be repelled, and the angle of *torsion*, or twist, will indicate the force of repulsion, or, what is the same thing, the relative amount of electrical charge given to A. It will be observed that the force requisite to twist a thread is in proportion to the angle over which the needle is moved, so that the angle of deflection is a true measure of the electrical repulsion.

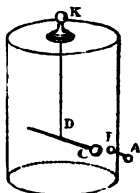


Fig. 66.

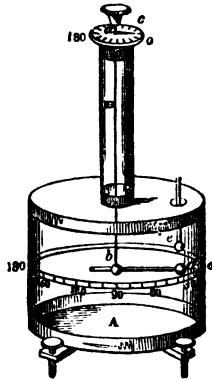
In comparing the intensity of two electrified surfaces, it is necessary that we should employ a **PROOF PLANE** (which is a round piece of gilt paper fixed to the end of a rod of sealing-wax or shell-lac), for the purpose of transferring the charges of electricity from the electrified surface to the ball A of the electrometer.

It is obvious that the torsion electrometer may be used, like the gold-leaf electroscope, for ascertaining whether a body is positively or negatively electrified.

Fig. 67. represents the form usually given to the torsion electrometer, where the thread *b* B, supporting the needle *b* d, passes through a tube mounted on the glass jar A. The circumference of the jar is divided into degrees, the zero point being opposite to the ball to which the electricity is trans-

ferred, so that the angle through which the needle is repelled may be at once seen. The needle is usually supported by a fine thread of silver, about two feet long, fixed at the top of the tube to a brass piece *c*, which admits of being turned tightly round the cap, which is also of brass, and fixed to the tube itself.

By means of the torsion electrometer, Coulomb proved that the law of electrical attraction and repulsion, as influenced by distance, is the same as the law of gravitation, that is, inversely as the square of the distance. He also determined the law regulating the distribution of the electric fluid on the surfaces of conductors.



*Fig. 67.*

## THE LEYDEN JAR AND ELECTRICAL BATTERY.


### EXPERIMENTS WITH A SINGLE LEYDEN JAR.

*Exp. 1. To give an electrical shock.*—Charge the jar after the manner described at page 34.; grasp the outside of the jar with one hand, and touch the knob of the jar with the other hand, and an electric shock will be felt. Care should be taken that the jar is not too strongly charged. Generally speaking, about half a dozen good sparks transmitted to the knob of the jar, will be a sufficient charge for giving any person a shock.

A shock may be given to any number of persons at the same time. Let them form themselves into a ring, by taking hold of each other's hands; let the first person grasp the outside coating of a jar which has been charged, and then let the last person in the ring touch the knob of the jar; the whole of the persons forming the ring will instantaneously receive the shock. The number of the persons forming the ring does not appear to affect the intensity of the shock.

*Exp. 2. To show the striking distance of the spark at discharge.*—Touch the outside coating of a charged jar with one ball of the jointed discharging-rod, gradually bring the other ball towards the knob of the jar; then, when they have come sufficiently near to each other, the electric spark will pass from one ball to the other with a snapping noise. The distance at which the discharge takes place depends upon the size of the jar and the intensity of the charge.

*Exp. 3. To show the manner in which a jar becomes charged.*—Place a common Leyden jar upon



the insulated stool, and bring the knob within striking distance of the prime conductor; turn the machine, and it will be found that the jar cannot be charged when its outside coating is thus insulated: now bring your knuckle near the outside coating of the jar; then, for every spark of positive electricity which passes to the interior coating of the jar, a corresponding spark of positive electricity will pass from the outside coating to the knuckle. The positive electricity is driven off from the outside coating on the principle of induction, while the negative electricity is held in a disguised condition on the outside coating by the attraction of the positive electricity accumulated on the inside coating. Hence it appears, that when the inside coating is charged positively, the outside coating is charged negatively; and that when the jar is being discharged, the two opposite fluids rush to each other.

*Exp. 4. To charge the inside of a jar negatively.*—Place the jar upon the insulated stool; bring the outside coating of the jar within the striking distance of the spark of the prime conductor; turn the machine, and at the same time, apply the knuckle to the knob of the jar; then, for every spark of positive electricity which passes to the outside coating, a corresponding spark of positive electricity passes from the inside coating to the knuckle, and thus the jar will become charged with negative electricity.

*Exp. 5. To show the principle of disguised electricity in relation to the Leyden jar.*—Let a jar be placed on the insulating stool, and let the ball *D'*, supported by a metal pillar, communicate with the outer coating of the jar. Suspend a ball of cork *F* by a linen thread, midway between the knob *D* of the jar and the ball *D'*, communicating with the ground by a metal chain *K*. Charge the jar after

the manner described in *exp. 3.* ; then the ball will be attracted to *D*, and, owing to the contact, a certain portion of positive electricity will pass to the ground through *K*, and a certain portion of positive electricity will remain DISGUISED on the inner coating ; *F*, being thus restored to its natural state,

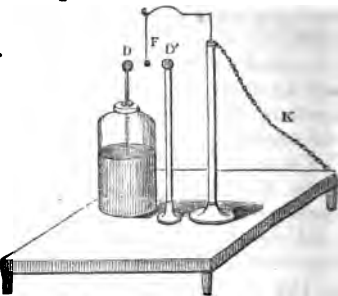


Fig. 68.

will be attracted to the ball *D'*, owing to the negative electricity set free from the external surface of the jar : when *F* comes in contact with *D'*, a certain portion of electricity will, in like manner, pass off from the outer surface of the jar through the conductor *K*, and then a certain portion of negative electricity will remain DISGUISED on the outer coating ; *F* will then be again attracted to *D* ; and so on. The ball *F* may continue to oscillate between the two knobs, *D* and *D'*, for several hours, at the end of which time the two coatings will have lost their electricity, by this succession of small discharges.

The apparatus represented in *fig. 69.* is intended to illustrate the same principle. The insulated balls on *F* are in connection with the inner coating, and those on *F'* are in connection with the outer coating. Charge the jar after the manner described in *exp. 3.* ; then the

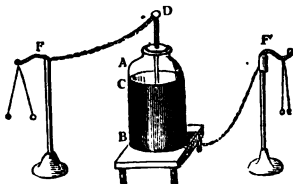


Fig. 69.

balls *F* will diverge with positive electricity, and the negative electricity will be held in a **DISGUISED** state on the outer coating. Touch the knob *D*, and the balls *F* will collapse, while the balls *F'* will diverge; the positive electricity is now in a **DISGUISED** state, while the negative is free; and so on, until all the fluid is taken from the jar.

*Exp. 6. To make a jar out of a common phial.*—Fit a cork to the phial, and pass a wire through it, reaching nearly to the bottom of the phial; put a knob on the outer extremity of the wire; half-fill the phial with water, and after carefully drying the outside, put the cork with its wire in its place; grasp the outside of the phial with one hand, and, after having taken a few sparks from the prime conductor to the knob, touch the knob with the other hand, and you will receive an electric shock.

Here the hand answers the purpose of the external coating of the Leyden jar, and the water that of the internal coating.

*Exp. 7. The electrical sportsman.*—This consists of a jar *J*, connected with the figure, *D*,

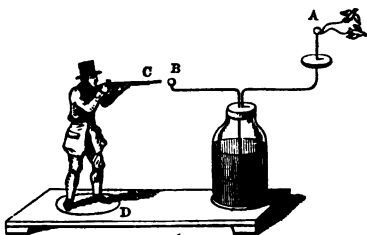


Fig. 70.

of a sportsman, who is supposed to be in the act of shooting some birds flying over the ball *A*. The knobs *A* and *B* are connected with the inner coating of the jar, and the knob *C*, at the extremity of the sportsman's gun, is connected, by a wire going down the figure, with the outer coating. The figure admits of being turned round upon a

pin, *D*, at its foot. Some light substances, cut in the shape of birds, are suspended by cotton threads from the ball *A*. Charge the jar; the birds appear to fly, owing to their mutual repulsion; turn the sportsman round until you bring the muzzle *C* of his gun within striking distance of the spark; at the moment the snap and spark of discharge takes place, the pith birds appear to fall down as if they were shot.

*Exp. 8. To ignite cotton.*—Tie a bit of cotton, mixed with a little powdered resin, on one of the knobs of the jointed discharger; place the other knob in contact with the outer coating of a charged jar; bring the knob, covered with the cotton, within striking distance of the knob of the jar; and the spark will ignite the cotton.

*Exp. 9. To perforate a card.*—Hold a dry piece of card-paper in contact with one of the knobs of the jointed discharger; discharge the jar through the card-paper, and it will be found to be perforated by the passage of the spark.

Discharge the jar through three or four pieces of card-paper, or through about a dozen sheets of writing paper.

The hole in the paper will be always found to be burred equally on each side, as if the electric fluid had come from the middle of the card.

*Exp. 10. The magic picture.*—This is simply a pane of glass placed in a frame, and covered on both sides with tinfoil within a few inches of the edges. It answers the same purpose as the Leyden jar. Charge one side of the

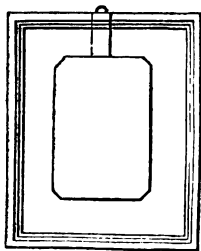
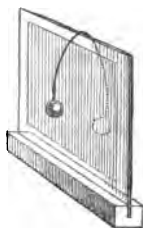


Fig. 71.

plate after the manner described in *exp. 3.*; discharge the plate in the usual way.

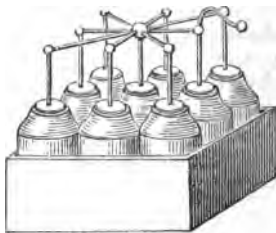
*Exp. 11. The electric pendulum.* — Make an electric pendulum of wire, with pith balls at the end of it, as represented in *fig. 72*. Balance the pendulum on the edge of a charged plate of glass; the pendulum will vibrate; the balls alternately strike the plate.



*Fig. 72.*

#### ELECTRICAL BATTERIES.

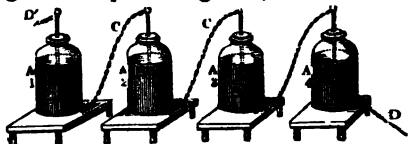
An electrical battery is formed when several jars are united together, by establishing a metallic connection between all their inner coatings, and a similar connection between all their outer coatings. The jars are placed in a wooden box lined with tinfoil, upon which the jars stand, and which forms the connection between all the outer coatings; the inner coatings communicate together by means of metal rods, which connect the various knobs of the jars together. The battery is usually discharged by means of a chain, which has one of its extremities fixed to the tinfoil of the case, and the other extremity attached to the knob of a discharging-rod.



*Fig. 73.*

It always requires time, even with a good machine, to charge a large battery. In order to accelerate the operation, a peculiar contrivance, repre-

sented by *fig. 74.*, has been adopted, called *charging by cascade*. Here each jar of the battery is placed upon an insulating stool, and the knob of each is connected by means of a chain, *c*, with the outer coating of the preceding one; the knob *D'* of the first jar *A<sub>1</sub>* is connected with the prime conductor, and the outer coating



*Fig. 74.*

of the last, *A<sub>4</sub>*, is connected with the ground by means of the chain *D*. When the machine is worked, the positive electricity from the outer coating of *A<sub>1</sub>*, in place of being driven away into the ground, serves to charge *A<sub>2</sub>*, by passing into its inner coating; in like manner, the positive electricity driven off from the outer coating of *A<sub>2</sub>* serves to charge *A<sub>3</sub>*; and so on, until the positive electricity is carried away from the outer coating of the last jar into the ground, by means of the chain *D*.

The battery is discharged by connecting *D* with *D'*.

#### DISCHARGING ELECTROMETERS.

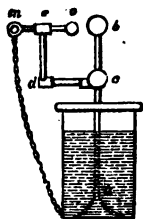
In these electrometers the intensity of the electricity is measured by the length of the spark at the instant of discharge.

*Lane's discharging electrometer.* — This is an ordinary Leyden jar, having an arm, *cde*, attached to the conducting wire *ab*; the horizontal part *cd* is of glass, coated over with shell-lac; the vertical part *de* is a brass rod, having a ring *e*, in which the graduated wire *mo* slides, and terminating in a knob *o*; the distance between the knobs *o* and *b*, and

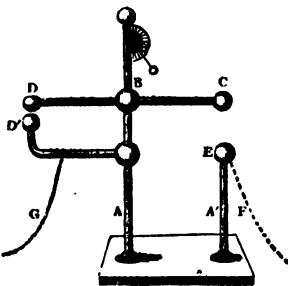
consequently the length of the spark, can thus be measured. To use the jar, connect the extremity *m* of the sliding wire, by means of a chain, with the outer coating of the jar, and then adjust the distance between the knobs *o* and *b* to suit the amount of charge which you wish to give to the jar. Bring the knob *b* near to the prime conductor, and continue to work the machine until the discharge takes place between the knobs *b* and *o*. If the knobs *b* and *o* are placed very near together, the intervening space will be penetrated by the spark, when only a small charge has been given to the jar; but if the distance between them be increased, then a more powerful charge may be given before the spontaneous discharge takes place. If the same distance between the balls *o* and *b* be retained, then the discharge will always take place when the same quantity of electricity has been transmitted to the jar. This jar may be used to test the relative powers of two electrical machines; in order to do this you place the balls *o* and *b* at a certain convenient distance from each other, then that machine will be most powerful which causes the jar to be discharged with the least number of turns of the handle.

*Cuthbertson's discharging electrometers.*

—This apparatus, represented in *fig. 76.*,



*Fig. 75.*



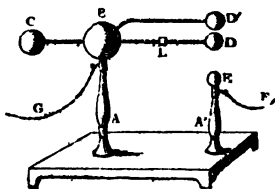
*Fig. 76.*

effects the discharge of itself, when the jar or battery has arrived at the limit of its charge.

An insulating support *A B* carries a metal rod *D C*, turning on a centre at *B*, like the two arms of a balance. This metal rod is connected with the inner coating of the jar, or battery, and also with a quadrant electrometer, as shown in the figure. Below the knob *C*, at a sufficient distance to prevent discharge, is another knob *E*, which communicates with the outer coating by means of the chain *F*; nearly in contact with the knob *D* is another knob *D'*, placed at the extremity of a metal rod, which is fixed to the same support as the rod *D C*, and, being in metallic communication with it, is also connected with the inner coating of the jar, or battery. When the jar has become sufficiently charged, the knob *D* is repelled from the knob *D'*, and the knob *C* is thereby brought nearer to the knob *E*, in connection with the outer coating, and when this distance is within the distance at which explosion takes place the jar, or battery, is discharged.

*Fig. 77.* represents a slightly different form of this apparatus, where *L* is a sliding ball, which enables the operator to give a more perfect adjustment to the action of the apparatus.

The balance electrometer simply consists of



*Fig. 77.*

with a scale hung on one side, for holding weights, and a gilt piece of wood hung on the other, for the purpose of being applied to the surface of an electrified body. The weight necessary for overcoming the attraction of the electrified surface on the gilt piece of wood, is taken as the relative

measure of the intensity of the electricity on the surface of the electrified body.

#### MECHANICAL EFFECTS OF ELECTRIC DISCHARGES.

The following experiments may be performed with a single jar, but the effects, in most cases, will be more striking when a battery is used.

*Exp. 1. The thunder house.*—This apparatus illustrates the use of metallic rods as a protection to buildings from the effects of lightning, and also shows the use of *pointed* rods as tranquil conductors of electricity. The conductor C D is broken at A and B, by two little square slips of wood, having conducting wires passing through them, and which may be inserted in their places, either with the conducting-wire broken, as at B in the figure, or with the conducting-wire unbroken, as at A; the ball C may be screwed off the wire, and then it is terminated by a point.

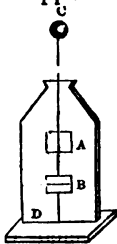


Fig. 78.

To use the apparatus. First let the ball C be screwed on the top of the conducting-wire, and let the square slips be placed as in the figure: connect the extremity D of the conducting wire with the outer coating of a charged jar; place one knob of the jointed discharger within striking distance of the ball C, and gradually bring the other knob of the discharger within striking distance of the knob of the jar; the disruptive effect of the charge will throw out the slip B, while A remains in its place.

Perform the same experiment when the ball C is taken off; the charge will pass quietly through the point, and both slips will remain in their place.

*Exp. 2 The electric bomb.*—A cavity is made in a block of wood C, and closed by A, cork D; two wires, A and

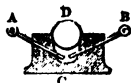


Fig. 79.

B, pass into this cavity, having their points about a quarter of an inch asunder. Now connect the knob B with the exterior coating of a jar, or battery; and with the knob of the discharging-rod in contact with the knob A, discharge the jar, or battery, and the cork will be forcibly projected from the cavity.

Fill up the cavity with sand; transmit a charge through it; and the passage of the spark will disperse the sand in all directions.

*Exp. 3. Dispersion of water.*—Transmit a strong charge through the fluid; it will be scattered in all directions.

*Exp. 4. To perforate glass.*—Fill a phial A (see *fig. 80.*) with oil; close it with a cork, through which a wire B passes, having its lower end so bent that its point shall touch the inner surface of the phial. Connect the extremity B with the outside coating of a charged jar; place the knob C of the jointed discharger opposite to the point, then discharge the jar, and the spark in its passage through the glass will make a hole.



*Fig. 80.*

This experiment may also be performed by suspending the phial from the prime conductor of a powerful machine, and taking the spark from the point, by bringing a brass ball opposite to it.

*Exp. 5. To break wood and glass.*—Transmit a strong charge through a stick of wood, in the direction of its fibres, about half an inch thick; the wood will be split.

Discharge a jar or battery through a plate of window-glass, after the manner described at page 70., *exp. 9.*; the glass will be broken.

*Exp. 6. To rupture substances which are imperfect conductors of electricity.*—Place several dry cards together between the knobs of the universal discharger; pass a strong charge through them, and

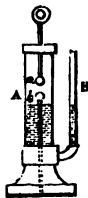
the spark will pierce a hole through them. The cards will have a peculiar sulphurous odour, like that which is felt in places after they have been struck by lightning.

Thin pieces of wood may be ruptured in the same manner.

Place a piece of dry writing-paper on the stage of the universal discharger, lay its knobs on the paper, at the distance of an inch and a half from each other, then transmit the charge, and the passage of the spark, if sufficiently strong, will tear the paper asunder.

Lay a piece of perforated tinfoil between two panes of glass; fix them tightly together, and transmit a strong charge through the tinfoil; the panes of glass will be split by the discharge.

*Exp. 7. An electrical thermometer*, sometimes called a *thermo-electroscope*. — This piece of apparatus, represented in *fig. 81.*, is intended to show the momentary expansion of the air produced by the heat of the spark in its passage through the air. A is an air-tight tube communicating with a small tube B, which is open at the top; *a* and *b* are two knobs, attached to the extremities of wires passing out of the tube; a coloured liquid below the level of the knob *b*, stands at the same height in the two tubes. When a charge or spark passes from *a* to *b*, the air in A expands by the heat developed by the passage of the spark; the liquid in A will therefore fall, while that in B will rise. The strength of the electric charge is indicated by the amount of expansion.



*Fig. 81.*

#### HEATING EFFECTS OF ELECTRIC DISCHARGES.

*Exp. 1. Ignition of resin upon water.*—Sprinkle some powdered resin on the surface of water con-

tained in a cup; connect the outer coating of a charged jar, by means of a chain, with the water in the cup; discharge the jar, by causing the spark to pass through the resin, which will instantly ignite.

Various other substances may be ignited in a similar manner.

*Exp. 2.* Place a skein of cotton, impregnated with any resinous powder, on the stage of the universal discharger; pass the spark through the cotton, and it will be ignited. This is another way of performing *exp. 8.*, explained at page 70.

*Exp. 5. Explosion of gunpowder.* — The igniting power of an electric spark is increased by passing the charge through a damp conductor. In this way we are enabled to fire gunpowder, which cannot be ignited by the spark under ordinary circumstances; place some fine gunpowder in the wooden cup *c* (*fig. 79.*), carry the fluid for about six inches along a damp thread attached to that arm of the discharger which is connected with the outer coating of the jar; then the passage of the spark from the end of one wire to the end of the other will ignite the powder.

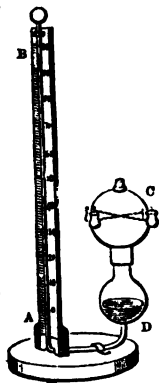
Here the moist thread, being a somewhat imperfect conductor, retards the passage of the electric fluid, and thereby causes the discharge to take place with less rapidity than it would otherwise do.

*Exp. 4. A fine wire heated, fused, and burned.* — Stretch a few inches of very fine harpaichord wire between the ends of the universal discharger (see *fig. 33.*); send a good charge through the wire, and it will be either rendered incandescent, or it will be fused. The length of wire which may be used depends upon the size of the battery and the intensity of the charge. A battery composed of half a dozen ordinary jars, and fully charged by a

good machine, will readily fuse about six inches of fine harpsichord wire.

The heating effects of electrical charges on different metals depends on their conducting powers; thus, platinum and iron, which are bad conductors of electricity, become more powerfully heated by the passage of an electrical charge than gold and copper, which are good conductors.

The thermo-electroscope, represented by *fig. 82.*, depends upon this principle. CDAB has the form of a differential thermometer; a platinum wire passes through the ball C, and is hermetically sealed to it. When an electric charge is transmitted through the platinum wire, it becomes heated, and this causes the air in the ball C to expand, which is instantly made manifest by the rise of the liquid in the tube A B. The graduated scale on A B gives the relative heating powers of different charges. This instrument is best adapted to the measurement of the heating power of voltaic electricity.



*Fig. 82.*

*Exp. 5. Ignition and fusion of gold-leaf.*—Place a strip of gold-leaf between two pieces of dry paper, lay them on the table of the universal discharger; pass a good charge through the gold-leaf, and it will be burnt. Both pieces of paper will be covered with a purple strip of oxide of gold; the strip has a greyish tinge when the gold-leaf contains a portion of silver.

*Exp. 6.* Place a small bit of gold-leaf between two pieces of window-glass, proceed as in the last experiment, and the gold will be fused into the glass.

*Exp. 7. Ignition of gilt thread.* — Stretch a gilt thread of silk between the extremities of the universal discharger; send a charge through the thread, and the electric fluid in its passage will burn the gilding, and the silk will remain uninjured.

#### PHYSIOLOGICAL EFFECTS OF ELECTRIC DISCHARGES.

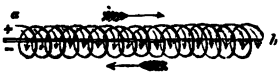
The sensation of a spider's web being drawn over the face, and the peculiar phosphoric odour attending the transmission of electricity, are amongst the most ordinary physiological effects of electricity. When a strong electrical charge passes through the body, it is accompanied by a shuddering sensation, and a sudden contraction of the muscles, which is called the **ELECTRIC SHOCK** (see *exp. 4.*, page 36.). The discharge from a single jar is sufficient to destroy the life of small animals, and the discharge of a powerful battery through the head of a large animal is enough to kill it.

*Exp. 1.* In taking a shock from a jar, interpose, in some part of the circuit, a damp rope, then, instead of the usual shock, there will be merely a tingling sensation produced at the tips of the fingers.

*Exp. 2.* Place the head of a live mouse between the wires of the universal discharger, send a strong shock through it, and the mouse will be instantly killed.

#### MAGNETIC EFFECTS OF ELECTRIC DISCHARGES.

*Exp. 1.* Place a small sewing-needle in a helix, or spiral, formed of copper wire, *a b* (*fig. 83.*), covered over with silk; place the ends of the helix in contact with the arms of the universal discharger; transmit



*Fig. 83.*

a strong charge through the wire, and the needle will be rendered magnetic. The end of the needle, which lies to the right of the electric current, will be a north pole, and the opposite end a south pole.

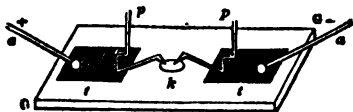
*Exp. 2.* Reverse the direction of the needle of the last experiment; transmit two or more charges of electricity through the helix, and the poles of the needle will be reversed.

The magnetic effects of common electricity are very feeble as compared with those of voltaic electricity. The explanation of these phenomena will be given in connection with the subject of galvanism.

#### CHEMICAL EFFECTS OF ELECTRIC DISCHARGES.

The chemical effects of the ordinary electric currents, like the magnetic effects, are comparatively feeble. The following experiments, however, show that ordinary electricity really possesses a decomposing influence.

*Exp. 1.* Place two pieces of tinfoil, *t t*, on a dry pane of glass, *G G*; on these pieces of tinfoil lay platinum wires, bent in the manner shown in *fig. 84.*, so that



*Fig. 84.*

there shall be a small space between the two points at *k*, where they touch the glass, and where the body which is to be decomposed is placed. Lay the glass *G G* on the table of the universal discharger, place its two knobs on the tinfoils, and connect one of them, by a chain and a moist thread, with the prime conductor of the machine, and the other with the insulated cushion. Place a drop of a solution of iodine of potassium at *k*, between the

platinum points ; turn the machine, and after a short time the iodine will be deposited at the positive wire, and the metallic potassium at the negative wire. Perform the same experiment with a drop of a solution of sulphate of copper, and so on.

These experiments may be performed with more delicacy, by using blotting paper saturated with the solutions ; thus, paper dipped in a solution of iodine in alcohol, will readily give a blue tinge of iodine on the paper in contact with the positive wire.

The decomposition of water, by common electricity, was first shown by Wollaston.

Sparks discharged for a length of time, through the air of a closed receiver, cause the two gases in the air to combine and form nitric acid ; in this way, no doubt, nitric acid is formed in the atmosphere by lightning.

*Exp. 2.* Place a fine metal point in connection with the prime conductor of the machine ; work the machine for some time, and then bring the metal point in contact with the tongue ; a faint acid taste is felt. Whereas the negative electricity will produce an alkaline taste.

## DISTRIBUTION OF ELECTRICITY ON THE SURFACE OF INSULATED CONDUCTORS.

*Exp. 1. The electric fluid arranges itself upon the SURFACES of conductors. — A is an electrified*

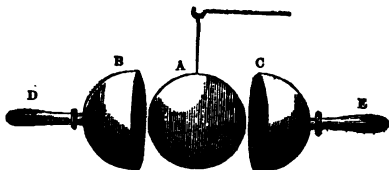


Fig. 85.

metal ball, suspended by a silk thread; B and C are two hollow metal hemispheres, which exactly envelope the sphere; when they are removed from the sphere, then not the slightest trace of electricity remains upon it, while the outer surfaces of the hemispheres contain all the electricity which was at first in A. This may be proved by means of the electroscope.

### *The Proof-plane.*

To show in a more complete manner the superficial distribution of electricity, a small piece of apparatus, called a PROOF-PLANE, is usually employed. This apparatus is represented in fig. 86., where C is a small disc of gilt paper, fixed at the end of a stick of gum-lac, A B. In using this instrument, a point of the electrified surface is touched by the proof-plane, which being carried to the torsion electrometer, the intensity of the electricity at the point touched by the proof-plane is indicated by the deflection of the needle.



Fig. 86.

*Exp. 2.* A is a conical muslin bag, fixed to an insulated metal ring, forming something like a butterfly net; B and C are silk threads attached to the apex of the cone, one on the outside, and the other on the inside, by which the cone may be turned outside in. Let the cone be charged with electricity by means of a carrier-ball; test the electricity of the inside and outside surfaces by means of the proof-plane; then it will be found, that while the outside surface is charged with electricity, the inside surface is entirely free from it. Turn the cone outside in, and test the surfaces as before; the surface which is now outside will contain all the electricity, and that which is now inside will be entirely free from it.

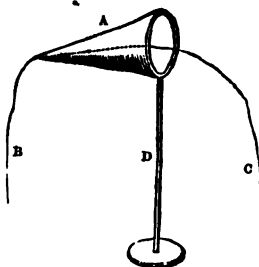


Fig. 87.

These experiments clearly show that the electricity distributes itself upon the exterior surface of a conducting body, but not on the interior surface.

The following experiment, first given by Faraday, establishes the same principle, as well as an

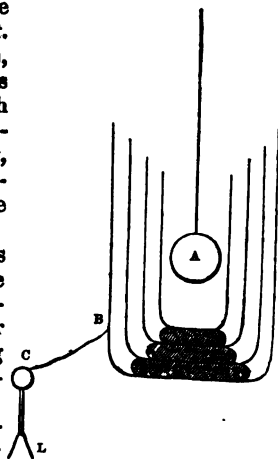


Fig. 88.

important law relative to the induction of electricity:—

An insulated electrified ball, *A*, is suspended in the interior of a series of jars, placed the one within the other, and separated from each other by plates of gum-lac, as shown in *fig. 88.*; the outer jar *B* communicates with a gold-leaf electroscope *C*, the leaves of which, *L*, diverge the moment the electrified ball *A* is introduced. Here induction takes place from jar to jar, until at last the outer surface of the jar *B* becomes electrified.

(1.) Upon testing the electricity on the surfaces of the jars by means of the proof-plane, it will be found, while the outer surfaces of the jars all contain electricity, the inner surfaces are entirely free from it.

(2.) While the gold-leaves *L* are divergent, let the electrified ball *A* touch the side of the inner jar, and it of course transmits its electricity to the jar, and the gold leaves neither diverge more nor less than before. This experiment proves that the electricity possessed by the ball is exactly equal in quantity and in power to that which it develops by induction.

“By applying his theoretical ideas to other and different phenomena of statical electricity, Faraday is led to admit that the tendency of electricity to distribute itself on the surface of conducting bodies is more apparent than real; and that the experiments which prove that there is not, in fact, any free electricity except at their surface, are easily explained in another manner. No electric charge, according to this theory, can be manifested in the interior of a body, on account of the opposite directions of the electricities in each of the interior particles; whence the resulting effect is null: whilst the induction exercised by exterior bodies renders the electricity sensible on the surface. From this manner of regarding it, electricity must show itself only on the surface of a conducting envelope, whatever be its conductivity, or the insulating property of the substance placed within. Faraday, in fact, demonstrated this by strongly electrifying oil of turpentine, placed in a metal vessel. There was no apparent electricity, except on the exterior surface of the vessel. He also constructed a cubical chamber, twelve feet square, the wooden

sides of which were covered outside with tinfoil: he insulated it; then, after having introduced into it electroscopes and other objects, he electrised the interior air with a strong machine. No trace of electricity was manifested within; whilst considerable sparks and luminous brushes darted off in all directions from the exterior surface. While these experiments complete those of Coulomb, in which he operated only upon conducting bodies, they render the explanation that was given rather improbable, since it was based upon the free propagation of electricity in the conducting mass; whence it followed that this electricity distributed itself entirely on the surface. When once the phenomenon has occurred in the same manner with insulating bodies placed interiorly, this explanation is not tenable.

With regard to the influence of form upon the quantity of electricity accumulated at the surface of bodies not spherical, it would always depend, according to Faraday's theory, upon some points of the surface being exposed to a greater amount of inductive forces than others. Thus the extremities of a cylinder, or of an elongated ellipsoid, would be more strongly electrised than the rest of the surface, because there go from them a greater number of filaments of polarised particles, establishing with surrounding conductors the communication necessary for induction. A point is far superior in this respect; for it is the centre whence emanate, in all directions, the lines of inductive force, which, for example, when a ball is in question, are found distributed over a greater extent, and do not set out from a single point only, but equally from all points of its surface.

In the theory that we have been explaining, the mutual repulsion of bodies charged with the same electricity is only apparent; it is called into existence because there is no electricity on the nearer surfaces, and because each of the bodies is attracted in opposite directions by the surrounding bodies, upon which induction determines an electrical state dissimilar to their own. We may even prove, by means of the proof-plane, that the two gold leaves of an electroscope, when they are diverging, have no electricity on their interior surface, whilst they are strongly electrised exteriorly, however thin they may be in other respects. Repulsion is also explained by attributing it to the attraction exercised upon each of the gold leaves by the contrary electricity, developed by induction, in the strata of air in contact with their exterior surface. This mode of action of the air is much more natural and more probable than that in which it is regarded as determining repulsion by the greater pressure from within outwards, than

inwards from without, which it exercises upon electrised bodies. However, the experiments which show that repulsion takes place *in vacuo* as well as air, would seem to be equally contrary to these two explanations, except that, in the former, we admit the effect by induction of the ambient bodies, even when they are placed at a great distance."

*Exp. 3. The intensity of the electricity upon a conducting body depends upon the extent of that surface.*—A B is an insulated metallic roller, which

may be turned by the insulated handle H; D is a pith-ball electroscope; C is a metallic ribbon coiled upon the roller. Let the roller be charged with electricity, then the balls D will diverge from each

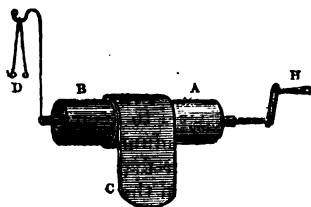


Fig. 89.

other, indicating the intensity of the charge; let the metallic ribbon be unrolled, drawing it by means of a silk thread attached to the extremity C; then the balls D will approach each other, owing to the electricity having become spread over a greater extent of surface: now let the ribbon be rolled up, by the insulated handle H, and the pith balls will again diverge from each other.

*Exp. 4 To show that electricity accumulates itself towards the extremities of an insulated conductor.*—Touch the different parts of the electrified conductor with the proof-plane, and test the intensity of the electricity in each case by means of the torsion electrometer, and it will be found that those parts of the conductor which are furthest from the middle have the greatest intensity. Hence the tendency of the electric fluid to escape from pointed extremities. These effects apparently arise from the mutual repulsion of the particles of the fluid.

## ATMOSPHERIC ELECTRICITY.

## THE IDENTITY OF ELECTRICITY AND LIGHTNING.

THE honour of this discovery belongs to Franklin. In a letter to a friend he gives the following account of the origin of the conception which conducted him to the great discovery :—" Your question, how I came first to think of proposing the experiment of drawing down the lightning in order to ascertain its sameness with the electric fluid, I cannot better answer than by giving you an extract from the minutes I used to keep of the experiments I made, with memorandums of such as I purposed to make, the reasons for making them, and the observations that arose upon them, from which minutes my letters were afterwards drawn. By this extract you will see that the thought was not so much an out-of-the-way one, but that it might have occurred to an electrician. 'Nov. 1749. Electric fluid agrees with lightning in these particulars: 1. giving light; 2. colour of the light; 3. crooked direction; 4. swift motion; 5. being conducted by metals; 6. crack or noise in exploding; 7. subsisting in water or ice; 8. rending bodies it passes through; 9. destroying animals; 10. melting metals; 11. firing inflammable substances; 12. sulphureous smell. The electric fluid is attracted by points. We do not know whether this property is in lightning, but since they agree in all the particulars in which we can already compare them, is it not probable they agree likewise in this? Let the experiment be made.'"

This letter will always be read with interest; affording, as it does, one of the most admirable examples of inducting reasoning.

Franklin made the experiment in the following manner. He made a kite with points fixed to it, with the view of drawing electricity from the clouds. In order to insulate the electricity that might pass down the hempen cord, which is a partial conductor of electricity, he attached a silk cord to its extremity, where he placed a key, from which he expected to obtain sparks of electricity. Afraid of being laughed at, should his experiment fail, he took his little boy with him, to make it appear as if he were going to assist the boy in flying his kite. Franklin and his little boy having raised their electrical kite in the air, they waited a long time before any indications of electricity could be seen. At length a thunder cloud passed over the kite; the electric fluid passed from the cloud to the points fixed on the kite, and descended down the hempen cord, the fibres of which stood erect by electrical repulsion; Franklin then applied his knuckle to the key, and received the electric spark.

What must have been the extacies of his soul at that moment! He had made one of the most brilliant discoveries in the whole range of physical science! he had discovered the identity of lightning and electricity!

He afterwards charged Leyden jars with lightning, and made other experiments similar to those usually performed with electrical machines. He also introduced lightning conductors, or pointed rods, for the protection of buildings from the effects of lightning. See *exp. 1.*, page 75.

The picture of Franklin and his little boy flying the kite which first drew lightning from the clouds, will be regarded with interest to the latest ages of the world.

About the same time, acting under Franklin's

suggestion, Dalibard erected an insulated pointed rod, 40 feet high, and thereby succeeded in obtaining sparks from the clouds.



*Fig. 90.*

#### ELECTRICITY IN THE AIR.

Electricity is always found in the air, but it varies both in kind and in quantity. It is generally positive when the air is clear and serene; and negative when it is humid and cloudy. The intensity of electrical phenomena is usually greatest in

the higher strata of the atmosphere: it is also stronger in winter, especially during frosty weather, than it is in summer, and when the air is calm than when it is boisterous. When the wind blows from the north, the drops of rain are generally positive, and when it blows from the south, they are generally negative. The earth is always in a contrary state of electricity to that of the higher strata of the atmosphere; and hence the atmosphere, at the height of a few feet above the surface, is always in a neutral state. The aerial electricity attains a maximum and minimum condition twice every day; its intensity is least during the night; it increases after sunrise, or during the fall of dew, and attains its maximum condition a few hours after sunrise: from that time it gradually decreases until a few hours before sunset, when it reaches its second minimum condition; after sunset it rises rapidly, especially during the fall of dew, and attains its second maximum condition a few hours after sunset.

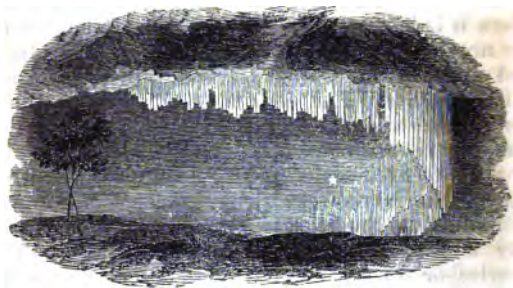
#### ELECTROMETEORS.

The most common electrometeors are thunderstorms, sheet lightning, the aurora borealis, water-spouts, whirlwinds, and the luminous appearance of pointed conductors. The commonest and grandest of these electrical phenomena are thunder and lightning.

#### THE AURORA BOREALIS, OR NORTHERN LIGHTS.

In the higher regions of the atmosphere, where the air is very much attenuated, the flashes of electric light give rise to the well-known phenomenon of the aurora borealis, or northern lights (see *exp.* 2., page 47.). This meteor is seen most brilliantly towards the arctic regions. *Fig.* 91. represents the appearance which it presents at its com-

mencement, where streams of electric light appear to move from the northern parts of the horizon to-



*Fig. 91.*

wards the magnetic zenith. Sometimes, even with us it assumes the form of a magnificent luminous bow spanning the horizon for thirty or forty degrees.

*Figs. 92. and 93.* represent some of the appearances of the aurora borealis at the north arctic zone,

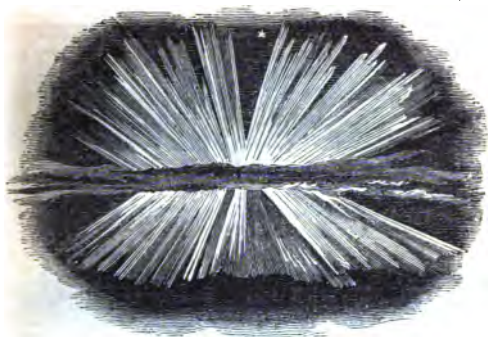


*Fig. 92.*

as given by M. Lottin, an officer of the French navy.

*Fig. 94.* represents a remarkable appearance of the aurora borealis, which was seen over every part

of Europe. This was observed and described by Mairan in the year 1726.



*Fig. 93.*

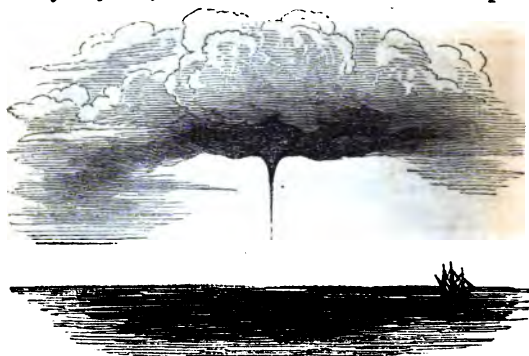


*Fig. 94.*

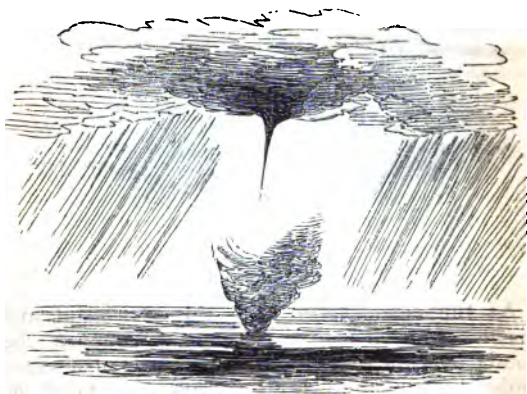
#### WATERSPOUTS.

At the commencement of this wonderful and terrific phenomenon, the watery vapour in the clouds appears to descend in the form of a cone, while the ocean beneath becomes agitated, as shown in *fig. 95.* ; the apex of the cone continues to descend, and, after a little time, a cloud of watery vapour rises from the ocean towards it, as shown in

*fig. 96.* This goes on until the two streams of watery vapour join each other and form a complete



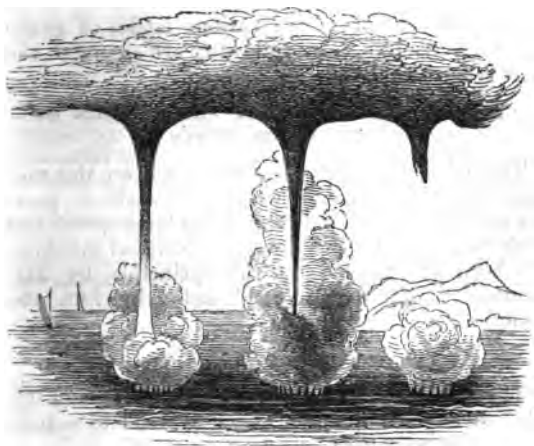
*Fig. 95.*



*Fig. 96.*

waterspout, or, it may be, form two or more waterspouts, as shown in *fig. 97.*

These remarkable phenomena appear to be due to the different electrical conditions of the cloud above and the ocean beneath.



*Fig. 97.*

## DIFFERENT MODES OF GENERATING ELECTRICITY.

BESIDES friction there are various modes of generating electricity. The following are amongst the most remarkable :—

### ELECTRICITY GENERATED BY THE FRICTION OF HIGH-PRESSURE STEAM.

The friction of high-pressure steam on the metallic pipes, &c., through which it is made to pass, has recently been found to develop large quantities of electricity. A very powerful electrical machine has been constructed on this principle by Mr. Armstrong of Newcastle, and called by him the Hydro-electric machine.

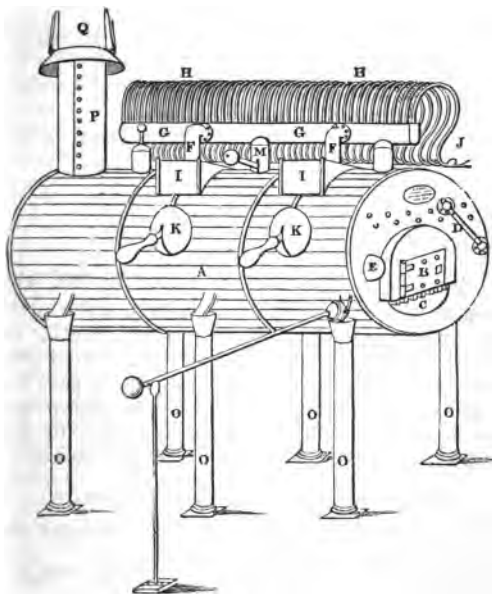
### HYDRO-ELECTRIC MACHINE.

This machine is represented in *figs.* 98. and 99. A is a strong steam boiler, cased in wood to reduce the radiation of heat, standing on six glass pillars, O ; B the furnace, and C the ash-pit, formed in the under part of the boiler ; P Q the chimney ; D is a water gauge, and E the feed valve ; F F two tubes leading from the valves L I to the large tubes G G ; H H are a series of bent iron tubes proceeding from the pipes G G, and terminating in jets J, which may be opened or closed, by means of levers placed at K K ; M is the safety valve.

*Fig.* 99. represents a zinc case, provided with four rows of brass points, which are placed in front of the rows of the jets J (*fig.* 98.), in order to attract the electricity from the steam vapour projected upon them : when long sparks are required, this case, with its points, is placed at the distance of about one foot from the jets ; and, on the contrary,



when a large quantity of electricity is required, the case is brought within a few inches of the jets. With



*Fig. 98.*

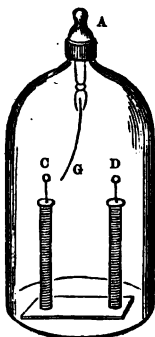
a view of augmenting the development of the electricity, the inner surfaces of the jets are lined with wood, forming a bent channel for the passage of the steam.

In this machine, we may regard the particles of water as serving the purpose of the glass plate of a common electrical machine; the wooden lining of jets as the rubber; and the steam as the rubbing power.

playing between the electrified knobs C and D; the knob B of the pendulum is alternately attracted and repelled by the electrified knobs C and D. This motion will often continue for years without intermission.

### *Bohnenberg's Electroscope.*

One of the most useful applications of the dry pile is exhibited in the construction of an electroscope, represented in *fig. 103.*, which is not only the most sensitive of all others, but has the additional property of at once indicating the peculiar kind of electricity of the body applied to it.



*Fig. 103.*

This instrument consists of two dry piles, C and D, placed as in Zamboni's perpetual motion; between the knobs C and D a single gold-leaf, G, is suspended in the same manner as in the ordinary gold-leaf electroscope. The moment the gold-leaf G is electrified by the approach of any electrified body towards A, it is carried either towards one knob or the other, according to the nature of the electricity with which the body is charged; that is to say, if the electroscope be charged with positive electricity, then the gold-leaf G will be attracted towards the negative knob of the pile, and so on.

THE END.

LONDON:  
A. and G. A. SPOTTISWOODE,  
New-street-Square.

# MAGNETISM.

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## THE MAGNETIC POWER.

SUBSTANCES endowed with MAGNETISM attract pieces of iron, and the substances possessing this property are called MAGNETS. Magnetic substances possess various other remarkable properties, which shall hereafter be described. There are two kinds of magnets, — natural magnets and artificial magnets.

*Natural Magnets*, or loadstones, are iron ores, found at almost every place on the earth. The ancient Greeks were acquainted with the attractive property of the natural magnet, or loadstone; they gave the name of magnet to this mineral, probably because it was found most abundant in the vicinity of Magnesia, a city of Lydia, in Asia Minor.

*Artificial Magnets* are generally made of steel bars, and the way in which the magnetic property is imparted to them will shortly be described. Artificial magnets are named according to their shape; thus, we have the *bar magnet*, represented in *fig. 1.*, and the *horse-shoe magnet*, represented in



*Fig. 1.*



*Fig. 2.*

*fig. 2.* When several bar magnets or horse-shoe

magnets are combined, the whole is called a *magnetic battery*, or a *compound magnet*.

The magnetic power of a magnetised bar chiefly resides in its extremities, which are called the magnetic poles; one being called the north pole of the magnet, and the other the south pole. In order to distinguish these poles from each other, a mark is usually drawn across the extremity corresponding to the north pole of the magnet.

One of the most remarkable properties of the magnet is, that it communicates its properties to a steel bar or needle that is rubbed for a few times, in the same direction, across one of its poles.

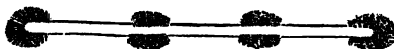
#### MAGNETIC ATTRACTION.

*Experiment 1.* Sprinkle some iron filings on a magnetic steel bar; the iron filings will be attracted to the extremities or poles of the magnet, whilst the other portions will be left nearly bare, as shown in *fig. 3*. When the steel bar exceeds eight or ten



*Fig. 3.*

inches in length, we *sometimes* find two other poles besides those that are at the ends, as shown in *fig. 4*.



*Fig. 4.*

*Exp. 2.* Attract a series of pieces of iron wire, *a, b, c*, to the extremity *N* of the magnetic bar *N S*, as shown in *fig. 5*. Here the wires, while they are in connection with the magnet *N S*, become a series of little magnets, whose lower extremities are all north poles; that is, of the same name as the pole of the magnet to which they are attached.



*Exp. 3. To magnetise a Pen-knife.* — Rub the knife, for several times, in the same direction, that is, from heel to toe, across one of the extremities, or poles, of a magnet; apply the point of the knife to some iron *Fig. 5*. filings, or small pieces of iron, — they will be attracted to the point of the knife.

*The Attraction between a Magnet and Iron is reciprocal.*

Whilst the magnet attracts iron, the iron also attracts the magnet.

*Exp. 1.* Suspend a piece of iron wire by a thread, so that the wire may hang horizontally. Bring the one extremity of a magnet near to one end of the wire; the wire will be attracted by the magnet.

*Exp. 2.* Suspend a magnetised needle in the same manner; bring the extremity of the iron wire near to either pole of the magnet; the magnet will be attracted by the iron wire.

*Magnetic Attraction transmitted through various Bodies.*

*Exp. 1.* Interpose a thin screen of wood, or glass, or copper, or any substance excepting steel and iron, between the magnet and the iron wire of the foregoing experiments; the attraction will take place just as if there were no substance interposed.

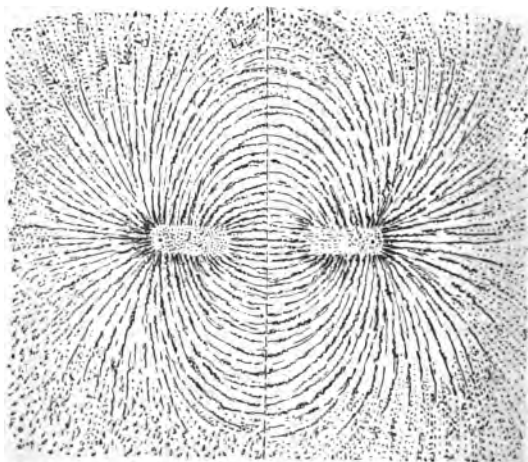
*Exp. 2.* Strew some iron filings on a sheet of white paper; place the pole of a magnet beneath them; the filings will appear to move in whatever direction the magnet is moved.

*Exp. 3.* Interpose an iron plate between a magnet and an iron wire suspended by a thread; the magnet will have little or no effect upon the wire.

*Distribution of Magnetism in a magnetised Bar.*

The inequality of this distribution may be readily proved by the following experiments.

*Exp. 1.* Strew some iron filings on a sheet of white card-paper, beneath which a bar magnet has been placed; occasionally tap the paper to facilitate the arrangement of the filings. The beautiful distribution of the filings (as exhibited in *fig. 6.*)

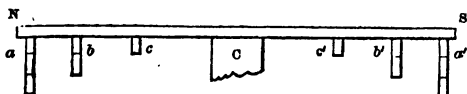


*Fig. 6.*

around the bar, shows the manner in which the attractive force of the different points in the bar vary, — the filings are most accumulated round the two poles, towards which they seem to converge from all parts, as to the principal centres of action: on the other hand, the central portion of the bar scarcely attracts any of the iron filings, thereby showing that the centre of the bar is a neutral point; that is to say, it does not possess any attractive power. The curves formed by the filings are known by the name of the magnetic curves.

This experiment furnishes us with a ready method of detecting the poles of a natural magnet.

*Exp. 2.* Take a magnetic bar, N S, *fig. 7.*, and



*Fig. 7.*

support it at its middle point *c*; apply at any number of equidistant points, *a*, *b*, *c*, *c'*, *b'*, &c., a series of pieces of soft iron wire; then it will be found that the number of pieces of wire which the magnet can support will increase as we approach the extremities or poles *N* and *S*.

The centre, *c*, of the bar has been called the *neutral point*, or *point of magnetic indifference*, and the poles are those two points where the greatest attractive force is found to reside, which in this case are at the extremities. The term pole is sometimes taken to mean that point in each half of the bar where the greatest attractive force will be accumulated, supposing the magnet to be acting upon a piece of iron or steel placed at a little

distance from it ; in this case the poles are, on an average, at the distance of about one-tenth of an inch from each extremity.

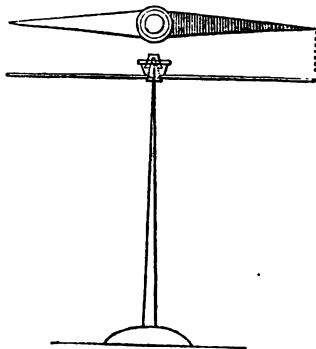
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## MAGNETIC POLARITY.

### DIRECTIVE PROPERTY OF THE MAGNETIC NEEDLE.

A MAGNETISED steel needle, suspended horizontally by a thread, or on a fine point, will always point very nearly north and south. This is called the *directive* polarity of the magnet. This direction is so constant, that, when the needle is displaced, it returns exactly to it, after a few vibrations. Moreover, the same extremity of the needle always points to the north, and the same extremity to the south ; so that if the needle be turned half-way round, it will not rest until it has resumed its original position. The extremity which points towards the north is called the north pole of the magnet, and that which points towards the south, the south pole of the magnet. This remarkable property has been of great use to navigators.

Magnetic needles are usually constructed after the form shown in *fig. 8.* ; where the needle turns upon a vertical point, which enters



*Fig. 8.*

the conical cap, screwed into the centre of the needle.

The direction in which the needle points has been called the line of the *magnetic meridian*. This line does not exactly coincide with the direction of the geographical meridian, as we shall hereafter more fully explain. At London, the needle at present points about  $24^{\circ}$  west of the true north. This is called the magnetic *VARIATION*, or magnetic *DECLINATION*. This declination is not the same for all places on the earth, and it is continually changing for all places on the earth.

*Exp. 1.* Magnetise a small sewing needle; place the needle on some water, so as to make it float: after a little time the needle will settle itself, and will point in the direction of north and south. If the needle be shifted from this position, it will return to the same position again when left to itself. This experiment may also be readily performed in the following manner:—

*Exp. 2.* Take a strip of card-paper *A B*; suspend it upon the point *s* of a pin passed through a cork, place the magnetised needle *N S* upon one side of the strip of card-paper; restore the balance by placing some small weight, *w*, upon the opposite side of the card; then the card will turn round until it points north and south, as before described.

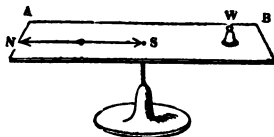


Fig. 9.

With any of these needles the following experiments may be performed (excepting the cases specified).

IRON OR STEEL ATTRACTS BOTH POLES OF THE  
NEEDLE.

*Exp. 3.* Hold a bit of iron near either of the poles of the needle; the needle will follow the iron; by moving the iron round, the needle will revolve on its centre in the same direction.

*Exp. 4.* By holding a bit of iron near to the sewing-needle of *Exp. 1.*, it may be made to float about in any direction.

*Exp. 5. The Magnetic Swan.*—This philosophical toy consists of a piece of thin sheet iron, made into the shape of a swan, so as to float upon water.

When the point of a magnet is presented to the swan, it appears to swim towards the point.

THE LIKE POLES OF MAGNETS REPEL ONE ANOTHER,  
AND THE UNLIKE POLES ATTRACT.

This law of magnetism is exactly analogous to the law of attraction and repulsion of the two kinds of electricity.

In order to distinguish these opposite influences, the magnetic principle of the north pole is called *positive magnetism*, or +, and that of the south pole, *negative magnetism*, or —.

*Exp. 6.* Bring the north pole of a magnet near to the south pole of the needle, and it will be attracted. Bring the north pole of a magnet near to the north pole of the needle, and it will be repelled; and so on.

This always enables us very readily to ascertain the particular poles of a magnet, or to determine

whether or not a metal bar possess magnetism ; for the extremity of the bar which attracts the north pole of a needle will be the south pole of the bar, and the other extremity will be the north pole.

*Exp. 7.* Hang a small key to the north pole of a magnet ; present the south pole of another magnet to the upper extremity of the key ; the key will instantly fall. Here the two different kinds of magnetism neutralise each other's effects.

*Exp. 8.* Immerse the like poles of two magnets into some iron-filings ; bring the two poles together, and the filings will fall. But if the poles are unlike, the filings will move towards each other.

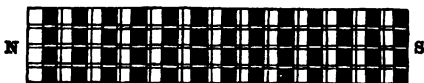
*Exp. 9.* Balance a bar-magnet upon a common pair of scales ; bring the pole of another magnet immediately beneath one of the poles of the magnet placed on the scale ; then, when the poles, thus brought near to each other, are of the same kind, the scale will ascend from the repulsion of the magnets ; and, on the contrary, the scale will descend when the poles are of different kinds.

IF A MAGNET BE BROKEN, EACH PART BECOMES A PERFECT MAGNET.

*Exp. 10.* Break a magnetised knitting-needle ; test the polarity of each end of the pieces ; the poles of the two magnets will lie in the same direction as the poles of the original magnet.

## THEORY OF MAGNETISM.

The theory of magnetism is exactly analogous to the theory of electricity. The magnetic fluid, in its quiescent state, is supposed to consist of two distinct fluids, the one being the NORTH or POSITIVE MAGNETISM, the other the SOUTH or NEGATIVE MAGNETISM. When these two fluids are combined, they form the magnetic fluid as it exists in non-magnetised substances, or substances in a neutral state. The particles of the same kind of magnetism repel each other, but the particles of opposite kinds of magnetism attract each other. When the two fluids exist in a body so as to neutralise each other, then the body exhibits no magnetism; but if this state of equilibrium be disturbed by any cause, then the magnetic state is induced. *Fig. 10.* gives a visible

*Fig. 10.*

representation of this supposed distribution of the particles of the two magnetic fluids in the body of a magnetic bar. Here we suppose the light squares to represent the particles of the positive fluid, and the dark squares the particles of the negative fluid. As the particles of the two fluids are separated from one another, they must arrange themselves according to the law of attraction and repulsion assumed in the theory; that is to say, a positive and a negative particle must always be contiguous to each other: from this it follows, that the extremity N will be a north pole, and S a south pole.

This theory readily enables us to explain all the phenomena of magnetism. Let us take a few examples.

1. When the extremity of a bar of soft iron is placed in contact with the north pole of a magnet, the opposite extremity of the bar also exhibits north or positive magnetism; this takes place in consequence of the repulsion of the positive fluid from, and the attraction of the negative fluid to, the north pole of the magnet.

2. When a magnetic needle is broken, it is obvious that the arrangement of the particles of the two fluids must remain unchanged; that is to say, the poles in the two magnets must lie in the same direction as the poles of the original magnet.

3. When the north pole of a magnet attracts a piece of iron wire, the extremity of the wire next to the north or positive pole of the magnet becomes a south or negative pole, owing to the repellant action exerted on the positive fluid, and the attractive action on the negative fluid of the wire, by the positive fluid of the magnetic bar; hence the magnet attracts the wire, according to the law, that bodies magnetised with different fluids attract each other. This also explains the great law of magnetic induction, which we shall shortly consider.

4. The like poles of two magnets repel each other, by virtue of the mutual repulsion subsisting between the particles of the same kind of magnetic fluid; and the unlike poles of two magnets attract each other, in consequence of the mutual attraction subsisting between the particles of the two different kinds of the magnetic fluid.

5. The north pole of the needle is directed towards the north pole of the earth, because the earth itself is a great magnet, having its negative magnetic

pole lying towards its north geographical pole, and its positive magnetic pole lying towards its south geographical pole.

6. The dip of the magnetic needle may be readily explained, by considering the dipping direction of the needle to be the direction of the resultant of the magnetic forces, residing in the earth, which act upon the needle. But this subject will be hereafter more fully explained.

THE ATTRACTIVE FORCE OF MAGNETS DECREASES  
WITH THE DISTANCE.

*Exp. 11.* Place the south pole of a magnet at a distance from the north pole of the needle, and a little to the right or left of it; then the needle will be deflected a little from its north and south direction; now bring the magnet a little nearer to the needle, and its deflection will be increased, and so on; thereby showing that the attractive force of the magnet increases as we decrease the distance.

It will also be observed, that the needle vibrates more and more rapidly as the magnetic bar is brought more closely to it. Now the rapidity of these vibrations obviously depends upon the amount of the magnetic force.

The law of the attractive force of a magnet, with respect to distance, is the same as the law of gravitation; that is to say, THE ATTRACTIVE FORCE OF A MAGNET VARIES INVERSELY AS THE SQUARES OF THE DISTANCE.

## MAGNETIC INDUCTION AND CONDUCTION.

WHEN a wire of soft iron is placed in contact with the pole of a magnet, it becomes, as it were, a part of the magnet itself; for *every portion* of the wire has the same polarity as the extremity of the magnet with which it is in contact. This may be called magnetic conduction. But if the contact be ever so slightly broken, the wire becomes a complete magnet having two poles, and this takes place in consequence of the operation of another principle, that of induction, which now claims our attention. When the soft iron wire has been entirely removed from the magnet, after a short time it no longer possesses any magnetic properties; it, in fact, was only decidedly magnetic while it was in contact with, or very near to, the magnetised bar. Soft iron receives the magnetic influence most easily, but it also parts with it most easily, when taken away from the magnet. Steel and cast-iron are not so easily magnetised; but when the magnetic property is once imparted to them, they retain it for years, unless they are subject to some counteracting influence.

*Magnetic induction* is that influence which a magnet exerts upon substances at a distance from

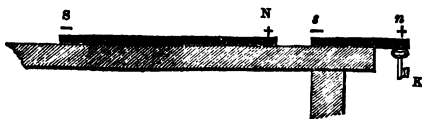


Fig. 11.

it. Let  $ns$  be a magnetic bar,  $n$  being its north

C

pole, and  $s$  its south pole;  $n\ s$ , a soft iron bar, having its extremity  $s$  placed near to the extremity  $N$  of the magnet; then the soft iron bar  $n\ s$  will be a perfect magnet, so long as the pole of the magnet  $N\ s$  is near to its extremity  $s$ ; the extremity  $n$ , in fact, will be its north pole, and  $s$  its south pole. To render the magnetic induction apparent, a small key may be suspended from the extremity  $n$ . The nearer the bar  $N\ s$  is brought to the bar  $n\ s$ , the more powerful will be the magnetism induced in it. Let the magnet  $N\ s$  be taken away; then, after a short time, the little key  $k$  will fall off the bar  $n\ s$ , and it will soon lose all traces of magnetism.

Here the positive fluid at  $N$  repels the positive fluid from the extremity  $s$ , and, at the same time, attracts the negative fluid; hence the equilibrium of the two fluids, in the soft iron  $n\ s$ , is disturbed, the extremity  $s$  being in a negative magnetic state, and the extremity  $n$  in a positive magnetic state; or, in other words,  $s$  becomes a south magnetic pole, and  $n$  a north magnetic pole.

Bring the south pole of a bar near to  $n$ , then the magnetic induction will be doubled; the lower extremity of the little key  $k$  will rise towards this south pole; and a much heavier key may be supported by the extremity  $n$ . Now bring the north pole of a bar near to  $n$ , then the key  $k$  will instantly drop off; in this case the two poles, being of the same kind, counteract each other's influence.

A series of soft iron bars may be magnetised in the same manner. Thus, let  $A$  be a strong magnetic bar;  $B$ ,  $C$ , and  $D$ , a series of soft iron bars placed near



Fig. 12



each other, as shown in *fig. 12.* ; then all these soft iron bars, from the action of induction, will become perfect magnets, having their poles as indicated by the letters of the figure.

The law of magnetic induction is exactly analogous to the law of electrical induction.

The following simple experiments will render the law of magnetic induction and conduction more apparent.

#### MAGNETISM BY CONTACT.

*Exp. 1.* Place a long piece of soft iron wire in contact with the north pole of a powerful magnet ; test the magnetism of the wire by means of a magnetic needle ; the south pole of the needle will be every where attracted by the wire, thereby showing that the wire possesses north polar magnetism.

*Exp. 2.* Cut some short pieces of iron wire ; present the end of one of them to the pole of a strong magnet ; it will be immediately attracted ; the free end of this wire will now attract a second wire, and this in its turn will attract a third wire, and so on. All these wires become little temporary magnets, owing to their connection with the pole of the magnetic bar. In like manner the phenomena of the iron filings adhering to the pole of a magnet may be explained : each filing, thus suspended, is converted into a little magnet.

#### MAGNETISM BY INDUCTION.

*Exp. 1.* Place the extremity of a long iron wire opposite to the north pole of a magnetic needle ; bring the north pole of a magnetic bar near to the opposite extremity of this wire ; the needle will be instantly repelled.

*Exp. 2.* Suspend two pieces of soft iron by a  
c 2

thread, as shown in *fig. 13.*; bring the north pole of a magnet close to the lower extremities of the wires; the wires will repel each other, after the manner shown in the figure.

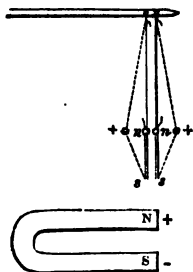


Fig. 13.

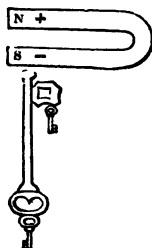


Fig. 14.

*Exp. 3.* Hold a large key near the pole of a powerful magnet; then, as the key becomes a magnet by induction, it will carry two small keys, one at its lower extremity, and the other at its upper extremity, as shown in *fig. 14.*

#### THE DIP OF THE MAGNETIC NEEDLE.

Besides the directive property, the magnetic needle, when freely suspended, has another remarkable property called its **DIP**, whereby its north pole dips towards the north pole of the earth in our hemisphere, and its south pole towards the south pole of the earth in the southern hemisphere.

At present the magnetic dip at London is about  $67^\circ$ .

This property may be readily verified in the following manner.

*Experiment.* Thrust a knitting needle *n s*



through a cork *c*, as shown in *fig. 15.*; at right angles to this needle, thrust a fine sewing needle through the cork which will form the axis of the needle *ns*; attach an untwisted thread *ad b* to the axis, and suspend the whole by the extremity of the thread, taking care to thrust *ns*, either one way or the other, until it is suspended in a perfectly horizontal position.

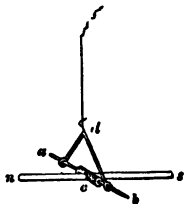


Fig. 15.

Now magnetise the needle *ns*, which may readily be done by simply keeping it for a short time across the two poles of a horse-shoe magnet. Again suspend the needle, and it will be found that its north pole will dip toward the north. Care must be taken, in magnetising the needle, not to disturb the axis.

This experiment may be performed with more precision by placing the axis *a a* between two upright supports *a b*, as shown in *fig. 16.* The best supports for the axis are the edges of two wine-glasses.

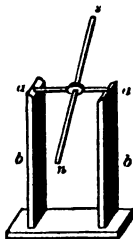
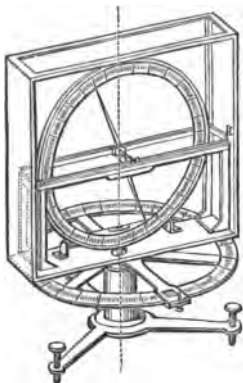


Fig. 16.

The angle which the DIPPING NEEDLE makes with the horizon at any place, is called *the angle of the needle's dip* at that particular place. This angle is not the same for all places. At places in the northern hemisphere the north pole of the needle is depressed, and at places in the southern hemisphere the south pole of the needle is depressed. At places near to the equator the needle has no dip, that is to say, it hangs horizontally.

Instruments constructed for the purpose of exactly observing the dip, have a vertical graduated circle connected with them, and also a screw adjustment for placing the axis exactly horizontal, as shown in *fig. 17*.



*Fig. 17.*



*Fig. 18.*

*Fig. 18.* represents a simple form of magnetic apparatus, for showing the direction of the needle as well as its dip. By this contrivance, the needle *n s* has a two-fold free motion, viz., a free motion with respect to its directive property, and a free motion, on its horizontal axis *f f*, with respect to the angle of its dip. *a b c d* is a light frame suspended by an untwisted thread; the horizontal axis *f f* of the needle turns freely in the sides *a b* and *d c* of the frame. A needle, thus suspended, will settle itself in the plane of the magnetic meridian, and will also assume the true angle of the dip.

The subject of magnetic variations, &c., will be more fully explained in connection with that of Terrestrial Magnetism.

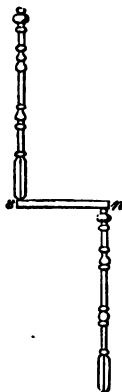
## TO MAGNETISE STEEL BARS, &c.

### I. TO MAGNETISE A NEEDLE WITHOUT USING AN ARTIFICIAL MAGNET.

Fix the needle, against the edge of a table, in the magnetic meridian, that is, nearly north and south; hold a long poker above the needle, and another one below it, as shown in *fig. 19.*; then move the pokers in contrary directions until they come to the positions shown in *fig. 20.*; repeat this operations for several times, always observing at every successive operation to move the pokers in the same manner, and the needle will be magnetised. Here the pokers, being held in the direction of the magnetic dip, really become magnets. (See the subject of Terrestrial Magnetism.)



*Fig. 19.*



*Fig. 20.*

### II. TO MAGNETISE STEEL BARS, &c., BY MAGNETS.

There have been various processes devised for magnetising steel bars, the following are amongst the most simple and efficient: —

*Most easy Methods of magnetising a small Needle.*

*Exp. 1.* Bring the pointed extremity of a sewing needle in contact with the south pole of a magnet; let the needle remain in contact for a few minutes; on separating them you will find that the pointed extremity has become a north pole, and the other a south pole.

Here it will be observed, that the end of the needle in contact with the pole of the magnet acquires an opposite or dissimilar magnetism to that of the pole. The equilibrium of the two magnetic fluids in the needle, is disturbed by the pole of the magnet, at the point of the needle, the dissimilar magnetic fluid is attracted by the pole, and the similar fluid is repelled.

*Exp. 2.* Rub one end of the needle, in the same direction, across the north pole of the magnetic bar, and then rub the other extremity of the needle across the south pole of the bar; then the former extremity of the needle will be a north magnetic pole, and the other extremity a south magnetic pole.

*Exp. 3.* Place the needle across the two poles of a horse-shoe magnet; let it remain there for some time; on removing it you will find that the extremity in contact with the north pole of the magnet has become a south pole, and the other a north pole.

*Exp. 4.* Place the middle of a needle on the north pole of a magnet; on separating them, you will find that the middle of the needle is a south pole, and that its extremities are north poles. This will form a pretty good astatic needle.

*Exp. 5.* With the pole of a good magnet, draw

any figure upon the surface of a clear steel plate; sprinkle iron filings upon it; the filings will remain suspended at all those points which the pole of the magnet has touched.

*Exp. 6.* Place one pole of a magnet in the middle of the steel bar; draw the magnet along to the end of the bar; return the magnet, through the air, to the middle of the bar, and repeat the stroke in the same direction; repeat this operation for several times. Next place the other pole of the magnet in the middle of the steel bar, and proceed as before, observing that, in this case, the magnet must be drawn to the opposite extremity of the steel bar.

This process has been called the method of *single touch*.

#### THE METHOD OF DOUBLE TOUCH.

This process consists in touching the steel bar which we wish to magnetise with both poles of the magnet at the same time. This method is always employed when large steel bars are to be magnetised.

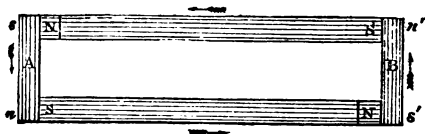
Fasten two bar magnets together, so that their dissimilar poles may be about  $\frac{1}{8}$  of an inch asunder; this will be most readily effected by inserting a piece of card-paper between them, and tying them with a piece of cord. Place this double magnet vertically upon the middle of the steel bar; draw the magnet to the end of the bar; return the magnet, through the air, to the other end of the bar; draw the magnet, as before, to the opposite end; repeat this process for several times, taking care to keep the pole of the compound magnet always in the same relative position, and to stop

the process when the magnet has arrived at the middle of the bar. The operation should be performed on both sides of the bar.

A horse-shoe magnet, having its poles near together, will answer the same purposes as the double magnet just described.

This method may be employed to magnetise two or more bars at the same time.

Place two steel bars, *N S*, *N S*, of the same size parallel to each other, and connect their extremities with two pieces of soft iron, *A* and *B* (see *fig. 21.*).



*Fig. 21.*

Place the pole of the double magnet on the middle of one of the steel bars, and move it completely round the frame, constantly keeping the poles of the double magnet in the same direction; when you have completed about a dozen revolutions, turn the plates and proceed as before. The poles of the steel bars will have a reverse position to the poles of the double magnet.

### *To magnetise Horse-shoe Bars.*

*Fig. 22.* shows the method of magnetising one horse-shoe bar *N*. Place a piece of soft iron *K*, called a *keeper*, across the extremities of the horse-shoe; place a horse-shoe magnet *M*, whose legs are at the same distance apart as those of the bar *N*, with its poles perpendicular to the keeper *K*; draw

the magnet towards the bent part of the horse-shoe; when it has arrived there, lift it off, and bring

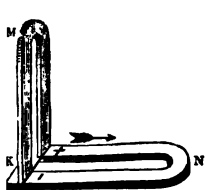


Fig. 22.

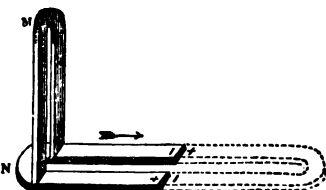


Fig. 23.

it back to its first position; repeat the operation for about a dozen times; then turn the horse-shoe bar with its keeper still on, and repeat the operation as before; and so on.

The polarity of each leg of the horse-shoe bar will be similar to that of the leg of the magnet first placed in contact with it.

Fig. 23. shows the method of magnetising two horse-shoe bars at the same time. The bars are placed with their extremities in contact, and the horse-shoe magnet *M* is moved from the curved part of one bar to the curved part of the other, constantly in the same direction.

The following is also a convenient and efficient mode of arrangement (see *fig. 24.*) for magnetising bars.



Fig. 24.

*M M*, is the horse-shoe magnet, placed with its poles against the extremities of the horse-shoe bar

to be magnetised ; A is a soft iron keeper extending between the legs of the horse-shoes ; this keeper, or feeder, is drawn in the same way as the magnet represented in *fig. 23*.

In the same, straight bars may be magnetised.



*Fig. 25.*

In *fig. 25.*, M M represents the magnet, A the feeder, B B, the two bars to be magnetised, and K their keeper.

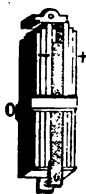
When magnetic bars are not in use, they should always be put away with their keepers upon them ; this not merely preserves their magnetism, but also tends to increase it.

A compound horse-shoe consists of a number of horse-shoe magnets bound together by screws, and connected at their poles by means of a keeper, as shown in *fig. 26*.

*Fig. 27.* represents a lot of bars bound together in the same manner.



*Fig. 26.*



*Fig. 27.*

### *On the best quality of Steel for making Magnets.*

"The steel best suited for artificial magnets is of a fine grain, of uniform structure throughout, and free from flaws. A principle requisite is, that it should possess a proper degree of hardness, and that it should be equally hardened throughout the entire mass ; for, if too hard, it is extremely dif-

ficult to impart to it any magnetic virtue; and, if too soft, it readily loses it when given. It has been found most advantageous to make the steel in the first instance brittle, like glass, and then to heat it a second time, till it becomes of a straw or violet colour.

The capacity and tenacity of artificial magnets are also affected by their form and dimensions. It has been ascertained that the breadth of a bar magnet should be about one-twentieth of its length, and its thickness from one-fourth to one-third of its breadth. In a horse-shoe magnet, the space between the two poles ought not to be greater than the thickness of the bar of which the magnet consists. Lastly, it is necessary that both bar and horse-shoe magnets be well polished, and that their faces be as level as possible.

*Magnetism is readily excited in soft Iron Bars.*

A bar of soft iron, placed in the direction of the magnetic dip, becomes magnetic, from the inductive influence of the earth acting like a magnet upon the bar. A few blows applied at one extremity of the bar, thereby causing its particles to vibrate, will generally aid the inductive influence of the earth.

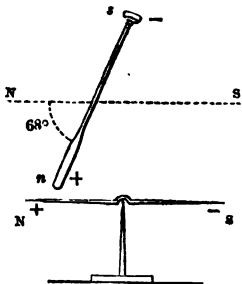
A bar of iron heated to redness, and allowed to cool after being placed in the direction of the magnetic dip, will acquire a certain degree of magnetism. Hence, pokers and iron rails, which have been kept for a long time standing in a somewhat vertical position, are generally found to possess a low degree of magnetism.

A piece of iron wire may be rendered magnetic by twisting it until it breaks; and in like manner

files and gimblets, after having been some time in use, become so much magnetised as to attract iron filings.

Voltaic electricity is the most powerful means of rendering bodies magnetic.

*Experiment.* Allow a magnetic needle  $N S$ , to assume its north and south direction: take a non-magnetised poker and hold it in a horizontal position, and at right angles to the direction of the needle, so as to bring one of its extremities, say its lower extremity, near to the north pole of the needle; the needle will of course, be attracted if the poker is not magnetic; now hold the poker in the direction of the magnetic dip, as shown in *fig. 28.*, and the north pole  $N$ , will be repelled, thereby showing that the lower extremity  $n$ , of the poker is a north magnetic pole. The effect will be increased by striking the head  $s$ , of the poker with a hammer.

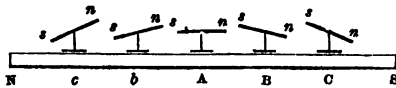


*Fig. 28.*

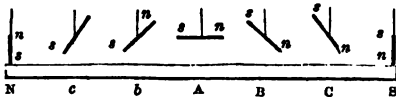
## TERRESTRIAL MAGNETISM.

IN order to account for the directive and dipping properties of the needle, it has been stated, that we must regard the earth as a great magnet, having a negative magnetic pole lying towards the north geographical pole, and a positive magnetic pole lying somewhere towards the south geographical pole. The following experiment is highly calculated to illustrate this theory.

*Experiment.* Place a magnetic needle (see *figs.* 29. and 30.) *n s*, over the middle part, *A*, of a magnetic bar *n s*; in this position the needle is exactly horizontal, and the south pole of the needle is directed to the north pole of the magnet, and the north pole of the needle to the south pole of the magnet. Thus we can assign a cause for the



*Fig. 29.*




*Fig. 30.*

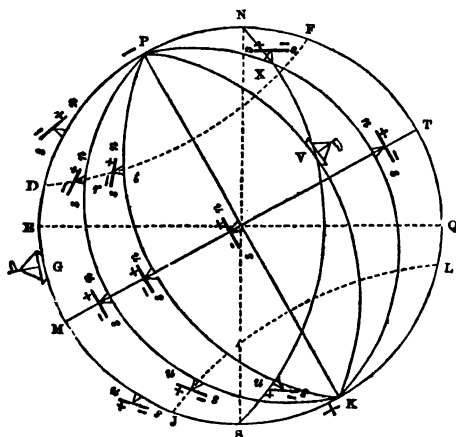
directive property of the needle. Now slowly move the needle along the bar from *A* to *s*; at the posi-

tion B, the north pole of the needle dips towards the south pole of the magnet; at the position C, the north pole of the needle dips still more towards the south pole of the magnet; and at S, the needle hangs vertically with its north pole pointing to the south pole of the magnet. Now in like manner move the needle from A to N; at the position *b*, the south pole of the needle dips towards the north pole of the magnet; and so on as before. (In *fig. 30*, the needle is supposed to be suspended by a thread.) Thus we can account for the magnetic dip.

The phenomena of the direction and dip of magnetic needles at different parts on the earth's surface, are found to coincide with the effects which a bar magnet produces on the needle, as above described; hence we are led to conclude that the earth is a great bipolar magnet, whose poles lie towards the geographical poles of the earth. As like poles attract and unlike poles repel each other, it follows that the magnetic pole of the earth lying towards the north is a negative magnetic pole, and that the one lying towards the south, is a positive magnetic pole. The former magnetic pole is situated in North America, in the vicinity of Hudson's Bay, in  $70^{\circ} 5' \text{ N. lat.}$ , and  $114^{\circ} 55' \text{ W. long.}$ ; and the other in  $72^{\circ} 35' \text{ S. lat.}$ , and  $152^{\circ} 30' \text{ E. long.}$  At these places, the dipping needle assumes a vertical position, as shown at P and K, *fig. 81*. Sir James Ross found the pole P, in the northern hemisphere during his arctic expedition of 1829. The actual existence of the magnetic poles in these places is further confirmed by the fact that the magnetic needle, at different parts on the earth's surface, is always directed towards these points as magnetic poles. At the MAGNETIC EQUATOR M T, the needle assumes a



horizontal position. As we approach the magnetic pole *P*, the north pole of the needle dips more and



*Fig. 31.*

more; and on the contrary, as we approach the magnetic pole *K*, the south pole of the needle dips more and more. On the MAGNETIC MERIDIAN *KGP*, *KVP*, &c., the needle has always the same general direction, although it varies in its dip. Let *NS*, represent the axis of the earth, *EQ*, its geographical equator, *SVN*, a geographical meridian; *KVP*, *KXP*, magnetic meridians; then the angles *PVN*, and *PXN*, will be the declinations, or angles of variation, of the magnetic needle at the points *V* and *X*, respectively. The commander of a ship at *V*, knowing from his charts the deviation of the needle at the particular spot, will be able to ascertain the true north and south. The

MAGNETIC PARALLELS D F, J L, &c., are LINES OF EQUAL MAGNETIC DIP, as shown at  $r$  and  $t$ , on the magnetic parallel D F, where the needles  $s n$ ,  $s n$ , dip towards the pole P, at the same angle.

It must be borne in mind that these different magnetic lines upon the earth, are not exactly formed by true sections of the sphere like the geographical circles. Indeed some of these magnetic lines have the shape of looped curves, or curves of double curvature, differing more or less from the circular lines shown in *fig. 31*.

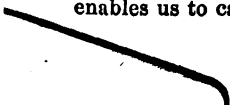
The lines of equal dip have been called ISOCLINIC LINES; these lines, as we have shown, surround the globe, running nearly parallel with the magnetic equator. It is a remarkable fact, that there is a coincidence subsisting between these lines, and the isothermal lines, or lines of equal heat upon the globe: this coincidence indicates that the earth's magnetism is intimately connected with terrestrial heat.

The inductive influence of the earth upon bars of soft iron (see *experiments*, p. 13. and 26.), bears a striking analogy to the induction of magnetism by ordinary magnetic bars. The magnetic effects of the earth are undoubtedly attributable to the inductive influence of terrestrial magnetism.

#### VARIATIONS OF THE NEEDLE.

The earth's magnetic powers are subject to both regular and irregular variations. These variations are indicated by the changes which take place, at the same place, in the declination and dip of the needle, and in its magnetic intensity.

The regular variations follow a certain law, which enables us to calculate beforehand the changes that



in future will take place. These regular variations are either secular or periodic. The secular changes become only evident after the lapse of years, and the periodic are those which, as it were, oscillate within short periods of time.

Of all the secular variations, the declination is that which has been most observed, and which has been most exactly determined. The dip and intensity have only recently claimed the attention of philosophers.

About the year 1600, the needle at London pointed  $4\frac{1}{2}^{\circ}$  to the east of the North; 1660 it pointed due North; from which time it gradually deviated to the west of the North until the year 1818, when it deviated  $24\cdot3^{\circ}$  to the west of North, which was its maximum deviation; but for the last 30 years its declination has certainly been decreasing, and in all probability it will continue to do so until it again becomes due North, then the declination will increase towards the East until the needle has again attained its maximum eastern declination, when it will again return.

All that is known with certainty relative to the dip of the needle, is that at present it is decreasing in Europe. The maximum dip of the needle at London took place about a century ago, when it was about  $74^{\circ}$ ; since that time it has been going on decreasing, with great regularity, at the rate of  $3'$  annually. At London the dip of the needle at the present time is about  $68^{\circ}$ .

The variation of the magnetic intensity has but recently claimed the attention of experimentalists; however, it seems highly probable that this intensity is at present decreasing in Europe.

The compass-needle, also, undergoes diurnal and annual variations. These variations appear to be

intimately connected with the heat of the sun. From sunrise to a little after noon, the north pole of the needle moves towards the west, and after that time it retrogrades towards the east until a little after sunset in the evening, when it remains nearly stationary until sunrise. The extent of these variations depends, not only on the time of the year, but also upon the situation of the place. In London, during the heat of summer, the variation is about 19', whereas, in winter, it is only about 7'. In Paris, the summer variation is about 15', and in winter about 9'. These variations disappear under the magnetic equator; and on the south of it they are found to exist in an inverted order.

The dip of the needle is also subject to daily variations, which also appear to depend upon the action of the sun's heat upon the earth; but they do not exactly accord with the daily variations of declination.

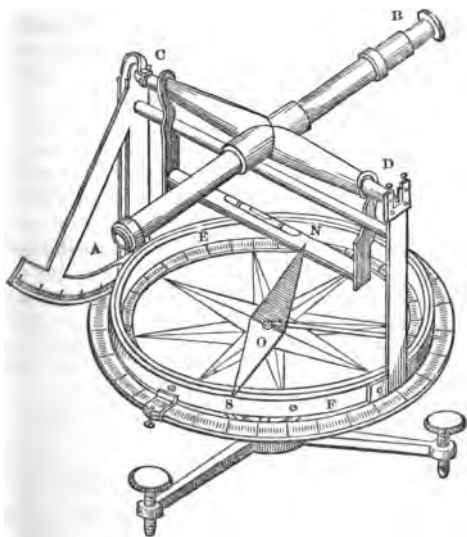
The variations of magnetic intensity also appear to depend upon the sun's heat.

The irregular magnetic variations are connected with certain electrical and meteoric phenomena, such as the aurora borealis, lightning, and even volcanic eruptions. A flash of lightning has been known to reverse the poles of a needle, and even to destroy its magnetism entirely.

#### THE DECLINATION COMPASS AND MARINER'S COMPASS.

This apparatus is used for observing and measuring the declination of the needle, or, conversely, for determining the north and south direction, or the meridian line, when the magnetic declination is known. It consists of a magnetic needle *ns* (see *fig.* 32.), delicately suspended by means of an agate or

steel cap *O*, resting on a pivot. *E F* is a graduated circle, on which is read the division corresponding to the position of the needle. The needle, with its graduated circle, is placed in a circular box covered with glass. The instrument is usually furnished with a telescope *A B*, turning on a horizontal axis *C D*, which carries an air-level and a vertical quadrant *A*, divided to measure the angles described by the telescope. The box is capable of turning

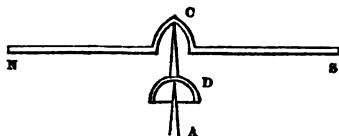


*Fig. 32.*

round on a vertical axis, by which it is fixed on its stand, in order to bring the telescope in the direction of the meridian ; then the angle formed by the di-

rection of the telescope, with the direction of the needle, gives the angle of declination; or, when the declination is known, the box is turned until the angle made by the axis of the telescope and the direction of the needle are equal to it; then this gives the position of the meridian.

THE MARINE COMPASS differs from the ordinary compass, simply in having a double suspension, which admits of its maintaining itself in a horizontal position, notwithstanding the rolling of the ship. *Fig. 33.* represents a form of this double suspension;



*Fig. 33.*

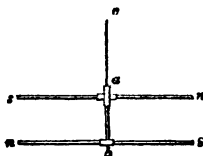
where *C* is the agate or steel cap fixed to the needle *N S*; *D* another cap, with a pivot fixed to its upper part, on which cap *C* turns; *A* the pivot on which the cap *D* turns.

#### THE ASTATIC NEEDLE.

For the purpose of conducting many interesting experiments, it is requisite to have magnetic needles, on which the earth does not exert any directing influence: needles of this sort are called *Astatic needles*. This object is readily attained by fixing two equal needles to a common point of suspension, with their contrary poles together. By this means the one needle exactly counteracts the directive tendency of the other, so that the compound or astatic needle will be free to obey the slightest

attractive force, without being influenced by the magnetic power of the earth.

*Fig. 33a.* represents a simple and highly serviceable astatic needle; *sn* and *ns* are two magnetic needles, of the same size and magnetic intensity, connected at their centres by a wire *ab*; the astatic needle thus formed is suspended by a fine thread of untwisted silk *ac*. The application of this astatic needle will be noticed in connection with the subject of electro-dynamics.



*Fig. 33a.*

### *The inclination compass.*

This apparatus is used for observing and measuring the dip of the needle at different places on the earth's surface, or at different periods of time at any place. See *fig. 17. p. 18.*

## AMPÈRE'S THEORY OF MAGNETISM AND ELECTRO-DYNAMICS.

AMPÈRE considered that a magnet is formed by a magnetic current, which he believed to be the same as an electric current, circulating round it constantly in the same direction, as shown in *fig. 34*. Supposing the magnet to have its north and south direction; then the current enters at the south poles, and circulates round the magnet spirally (like a corkscrew), along its length



*Fig. 34.*

from south to north, as shown in the figure ; that is, the current is directed from east to west in the lower face of the magnet, and therefore from west to east in its upper face ; or, in other words, the current is ascending in the face situated on the west, and descending in the face on the east. Steel bars become magnets when this regular current is permanently excited in them. Ampère established this theory by showing, that a helix of copper-wire, through which an electric current is transmitted, possesses all the properties of a magnetic needle. As a necessary consequence of this theory, it follows that parallel currents moving in the same direction mutually attract, and that they mutually repel when they are moving in a contrary direction. Now wires conducting electrical currents have really this property. This explains why like poles repel and unlike poles attract. But this theory will be more fully explained in connection with the subject of electrodynamics.

## VOLTAIC ELECTRICITY.

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**GALVANISM** or Voltaic Electricity is produced by a certain chemical action upon two different metals when brought into contact. Galvani, of Bologna, observed that when he touched a nerve and muscle in the leg of a dead frog with two different metals, on bringing these metals into contact, the leg underwent a convulsive motion, as shown in

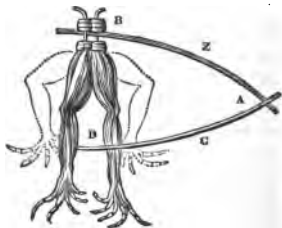


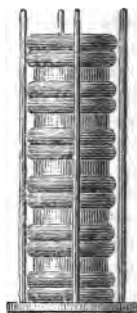
Fig. 35.

fig. 35., where *z* and *c* are the two metals brought into contact at *A*, the extremity *B* being in contact with the nerve, and *D* with the muscle. Galvani considered this effect as due to something in the animal structure, and hence he called it *animal electricity*, but, out of respect to the discoverer, the name of *galvani electricity* was given to it. But Volta soon after showed, that the effect was entirely due to the production of electricity by the action of the two metals upon each other, and that the nerves and muscles of the animal merely exhibited the free electricity, in the same way as any other delicate electroscope might do. This leading conception conducted him to a series of splendid discoveries, and in particular in the first year of the present

century, led him to the construction of the voltaic pile, which stands in the same relation to voltaic electricity that the common electrical machine does to frictional electricity.

#### VOLTAIC PILE.

A number of circular plates of copper and zinc, and of cloth or card, about 3 inches diameter, were provided, and arranged in the form of a PILE, *fig. 36*. The base of the pile is a copper disc, upon which a zinc disc is placed (these two discs form what is called a pair); over this pair a second similar pair is placed, observing always that the copper is below the zinc; the second pair is separated from the first by the circular cloth or card, moistened with a weak saline or acid solution. Upon the second pair is placed a third, separated also by a moistened circular piece of cloth or card, similar to that which preceded. In this manner a considerable number of pairs are placed in the same order, one over the other, and retained in their upright position by means of rods of glass. When the base-plate of the pile rests upon an insulating plate of glass, this lower plate is found to be charged with negative electricity, whilst its upper plate is charged with positive electricity. These extremities are called the poles of the pile or battery, the lower extremity being the negative pole, and the upper extremity the positive pole. If the metals had been placed in a reverse order, then the poles would also obviously be reversed. Two wires, one leading from the extreme copper-plate,

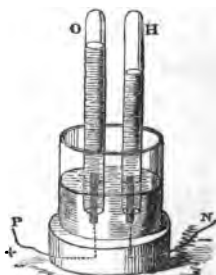


*Fig. 36.*

and the other from the extreme zinc-plate, conduct the electricity of the respective poles to any substance upon which the electric fluid is required to act. When the extremities of these wires are brought together, an electric spark passes between them, arising from the neutralisation of the two different kinds of electricity. When these wires are held one in each hand (the number of pairs in the pile being sufficiently great), a rapid succession of shocks are felt. When the extremities of the two wires are connected by a very fine platinum or silver wire about half an inch in length, the neutralisation of the two electricities causes this fine wire to rise in temperature, and to become red-hot. The length of the fine wire, which may thus be rendered incandescent, is in proportion to the power of the pile.

When the two wires proceeding from the two poles of pile are immersed near each other in acidulated water, the water is decomposed into its two constituent gases, hydrogen and oxygen, the oxygen being liberated from the wire proceeding from the positive pole, and the hydrogen from the wire proceeding from the negative pole; the volumes of the gases are constantly in the same proportions that constitute water; that is to say, one volume of oxygen to two volumes of hydrogen, as shown in *fig. 37*. In this experiment, the submerged parts of the two wires must be platinum.

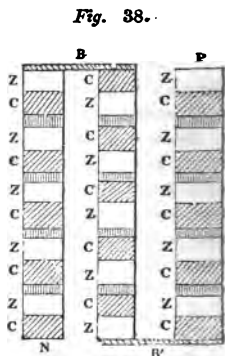
These phenomena are merely simple examples of the various



*Fig. 37.*

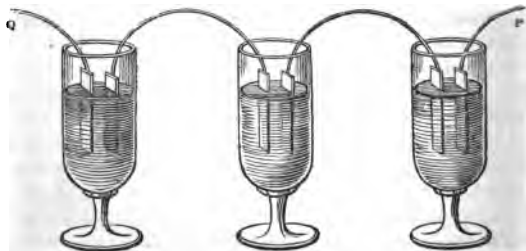
and important effects produced by the action of the voltaic pile or battery, which we shall hereafter more fully consider.

When the number of pairs in the pile is so great that its height would be inconvenient when placed in a single column, the plates may be arranged in two or more columns, as shown in *fig. 38.*, where the continuity of the pile is sustained by the bars B and B'. In this case the negative pole of the pile is at N, and the positive pole at P, and the effect of the whole is the same as if the second were placed over the first, and the third over the second.



Volta proposed a second arrangement of the pile or battery, called the *Couronne de Tasses*.

This form of the apparatus is represented in *fig. 39.*; it consists of a series of cups or glasses,



*Fig. 39.*

containing a saline or acidulated solution. Each pair of copper and zinc plates is immersed in the separate cups; the zinc plate in one cup being connected by a wire with the copper plate in the succeeding cup, and so on; the wire Q, proceeding from the first zinc plate, forms the negative pole of the battery, and the wire P, proceeding from the last copper plate, forms the positive pole of the battery; the same, in matter of fact, as in the ordinary pile just described.

Very great improvements have been made in the construction of these batteries; but before we proceed to describe them, we shall give a few simple and instructive experiments, calculated to elucidate the general principles and effects of voltaic electricity.

#### PRELIMINARY VIEWS AND SIMPLE EXPERIMENTS ON VOLTAIC ELECTRICITY.

*Exp. 1.* Place a piece of sheet-zinc *under* your tongue; lay a half-crown *upon* the tongue; no peculiar sensation is felt so long as the two metals do not touch each other: now bring the edges of the two metals in contact with each other; a disagreeable taste, something like copperas, is instantly excited.

Here the saliva on the tongue between the two metals is the exciting cause of the development of the electric fluid; and when the edges of the metals are brought into contact, the voltaic circle is formed, and the peculiar sensation of taste is the effect; but when the voltaic circle is broken this sensation instantly ceases. The peculiar taste of porter, when drunk out of a pewter pot, is also due to the same cause.

*Exp. 2.* Instead of the half-crown, in the last experiment, use a piece of charcoal or a piece of cast-iron.

*Exp. 3.* The first experiment gave you a *taste* of voltaic electricity; now the following experiment will give you a *sight* of it.

Place a silver spoon between the gums and one cheek, and a strip of zinc in a similar position on the other cheek; complete the voltaic circuit, by bringing the extremities of the metals together on the outside of the mouth; a slight flash of electric light will instantly be seen. Repeat the experiment: the flash will always be seen at the instant the two metals are brought into contact; and a smaller flash will be seen at the instant the contact is broken. The first experiment may be also performed by the silver teaspoon and the zinc-strip.

*Exp. 4.* Lay a five-shilling-piece on a larger plate of zinc; on the coin place a live leach or a live snail; so long as the creature does not come into contact with the zinc, he appears perfectly at his ease; but the moment he moves, so as to touch the zinc, thereby completing the connection between the two metals, he receives a shock and instantly recoils.

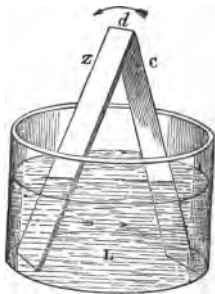
*Exp. 5.* Place a silver spoon *s*, in a glass containing a solution of sulphate of copper; into the same glass insert a strip of zinc *z*. No change takes place, in either of the metals, so long as they are apart: bring the upper ends of the metals in contact with each other; the silver spoon will become coated with copper, which will adhere so firmly that mere friction will not take it off.



Fig. 40.

This experiment fully illustrates THE ELECTRO-TYPE PROCESS.

*Exp. 6.* Place a slip of copper *c* (see *fig. 41.*), in a glass containing hydrochloric acid; into the same glass insert a strip of zinc *z*; so long as the metals remain apart, no chemical action can be seen, and no electricity is developed; bring the upper extremities *d*, of the metals into contact; active decomposition immediately begins; the chlorine combines with the zinc, and the hydrogen set free, makes its appearance at the surface of the copper in the form of minute bubbles,—voltaic electricity is in action. Withdraw the extremities of the metals from each other,—the electrical circuit is broken—electrical action no longer exists; restore the contact, and the electrical action is again renewed.



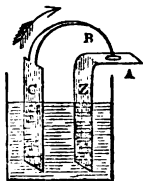
*Fig. 41.*

The disengagement of electricity is always in proportion to the chemical action; and the metal, which is most acted upon by the fluid, gives off its negative fluid to the other plate, and the consequence of this is, that the current proceeds from this latter plate to the former. In the experiment just given, the zinc plate is acted upon by the acid, and the voltaic current proceeds from the upper extremity of the copper plate to the zinc plate, as shown in the figure.

The cheapest acid for generating small portions of voltaic electricity with zinc and copper plates is

sulphuric acid, diluted with about twelve parts of water to one of the strong acid.

*Exp. 7.* Bend the zinc *z*, as shown in *fig. 42.*; place a bit of blotting paper, moistened with iodide of potassium, upon the zinc at *A*; bring the extremity *B* of the strip of copper *c* (or platinum), in contact with the moistened paper; the current of the electric fluid passes in the direction of the arrow; the iodide of potassium is decomposed by the electric current; the iodine is evolved at the positive pole, and the alkali, free potassa, at the negative pole.



*Fig. 42.*

The experiment will be more striking if a drop of a solution of starch be also added to the moistened paper.

*Exp. 8.* Perform the same experiment with the bibulous paper moistened with prussiate of potassa, slightly acidulated with hydrochloric acid.

*Exp. 9.* Twist a piece of copper wire in the form of a spiral or helix, round a small glass tube; connect the extremities of the wire with the zinc and copper plates immersed in diluted sulphuric acid; insert a steel needle into the glass tube; after a short time the needle will be found to be powerfully magnetic.

*Exp. 10.* Bend a piece of soft iron wire *H*, into the form of a horse-shoe magnet; twist a piece of copper wire, covered with silk or cotton, round this wire as shown in *fig. 43.*; connect the extremities of this wire with the voltaic plates *z* and *c*; the horse-shoe wire *H*, instantly becomes a magnet. If you have not got any covered wire at hand, wrap a piece of paper round the horse-

shoe wire before you twist the copper wire round it.

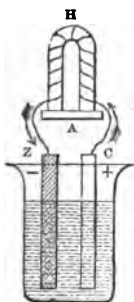


Fig. 43.

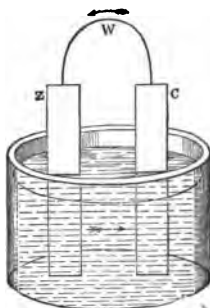


Fig. 44.

*Exp. 11.* Place the copper wire C Z, connecting the voltaic plates, in the plane of the magnetic meridian; bring a magnetic needle exactly over the wire C Z; the needle will be deflected from its north and south direction by the action of the wire C Z, conducting the voltaic current: now bring the needle exactly below the wire C Z; the needle will be deflected to the side opposite to that towards which it was before deflected.

REMARKS RELATIVE TO BATTERIES GENERALLY  
AND TO THE DIRECTION OF THE VOLTAIC CUR-  
RENT.

*Fig. 45.,* represents a single pair of zinc and copper plates acted upon by a diluted acid; the

connecting wire *c z*, shows the direction of the electric fluid; that portion of the copper plate which is immersed in the acid, becomes charged with negative electricity, and, as a necessary result of the law of electrical repulsion, the positive fluid is driven off from the upper extremity, hence the direction of the current. In all batteries, the current will always proceed from the wire attached to the metal least acted upon by the decomposing fluid.

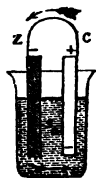


Fig. 45.

In Volta's battery, represented in *fig. 39.*, of which all other batteries may be regarded as mere modifications, the wire *P*, attached to the last copper plate will be a positive or + pole, and the wire *Q*, attached to the first zinc plate will be a negative, or - pole.

*Fig. 46.* represents a voltaic arrangement of two plates *Pt.*, *Pt.*, of the same metal, viz. platinum, immersed in different fluids, *A*, an alkali, and *c*, concentrated nitric acid, separated by a porous partition *a b*. The platinum immersed in the alkali becomes positively electrified, and that in the acid negatively electrified, and the current flows as shown in the figure.



Fig. 46.



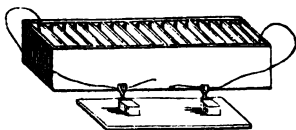
Fig. 47.

*Fig. 47.* shows the voltaic action which takes

place, when different metals are immersed in different fluids. The platinum plate Pt., is immersed in concentrated nitric acid M, and the zinc plate Z, in concentrated sulphuric acid S, the two acids being separated from each other by the porous partition *a b*. In this case the most intense electromotive tension is excited, the one metal being immersed in that fluid which renders it most powerfully negative, and the other metal in that fluid which renders it most powerfully positive. This is the principle upon which Groove's battery acts, which is certainly the most powerful that has yet been constructed.

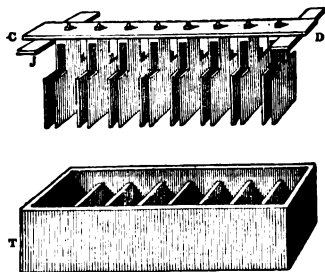
#### DIFFERENT FORMS OF THE VOLTAIC BATTERY.

*Cruikshank's battery*, represented in *fig. 48.*, consist of an oblong trough of baked wood, divided into cells, to be filled with acid, by a number of pairs of rectangular plates of zinc and copper. This form was a decided improvement on the common pile, but still it had several inconveniences in practice.



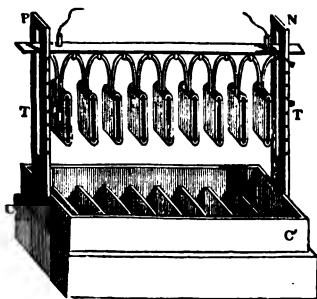
*Fig. 48.*

The arrangement represented in *fig. 49.*, removed many of these inconveniences. It is merely a slight modification of the Couronne de Tasses, represented in *fig. 39.* The trough T, with its cells, is made of Wedgewood-ware; the plates of zinc and copper, forming each pair, are soldered together by a connecting rod at the top, leaving them sufficiently apart at the bottom to span the partitions of the trough. The plates, thus joined in pairs, are all attached to a wooden bar C D, by which they may

*Fig. 49.*

be readily let down into the trough, when they are required to be in action, or withdrawn from the trough when the action is to be suspended.

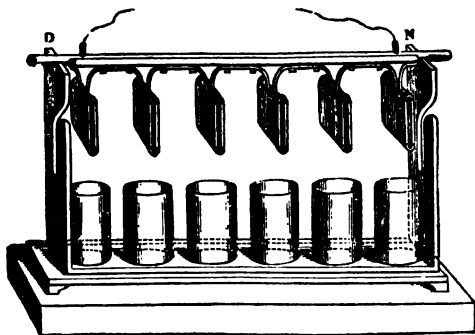
The greatest advantage attending this arrangement is, that by simply raising the plates, the fluid may remain in the trough while the action of the battery is suspended.

*Fig. 50.*

*Wollaston's battery.* Wollaston, having dis-

covered that the effect of the foregoing battery was augmented by increasing the surface given to the copper, he enveloped the zinc plate of each pair with the copper plate of the preceding one, taking care, at the same time, to avoid all metallic contact between these two plates. By this arrangement, the copper plate has double the surface of the zinc plate.

*Fig. 51.* represents a more convenient form of this battery, where the trough is replaced by a



*Fig. 51.*

series of glass jars. The acid can be more easily changed or discharged from these separate cells, than from the cells in the trough of the preceding form of the apparatus.

**THE HELICAL BATTERY.** In this battery the zinc and copper are wound into the form of a helix, and plunged into a glass vessel, containing the diluted acid; the helix of the zinc, in each pair, must not be in metallic contact with that of the

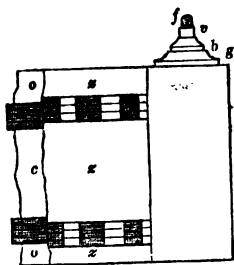


Fig. 52.

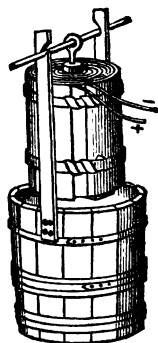


Fig. 53.

copper; but the helix of zinc in one vessel must be in metallic communication with the helix of copper of the succeeding pair, and so on, as in Wollaston's battery. *Fig. 52.* shows the manner of forming each pair of helixes, and *fig. 53.* the trough adaptation for each pair. This arrangement presents a great surface of metal in each pair to the action of the acid, without the necessity of having very large troughs. The acid mixture for charging this battery, is water mixed with  $\frac{1}{40}$ th in volume of strong sulphuric acid, and  $\frac{1}{80}$ th of nitric acid.

The batteries hitherto described, all have one decided inconvenience, viz., that after a short time they lose their power, which occasions them to act with a variable force during the same course of experiments. The zinc plates soon become covered with sulphate of zinc, and the copper plates with hydrogen and even oxide of zinc; these deposits not only greatly reduce the power of the

battery when in use, but also require the plates to be cleaned before being put into action again. In order to avoid these inconveniences, Daniell, Grove, and Bunsen invented their constant batteries.

CONSTANT BATTERIES.

These batteries are constructed on the principle explained in connection with *fig. 47.*, p. 46. ; where the porous partition, without interrupting the conduction of the voltaic fluid, prevents the accumulation of depositions upon the plates.

DANIELL'S CONSTANT BATTERY.

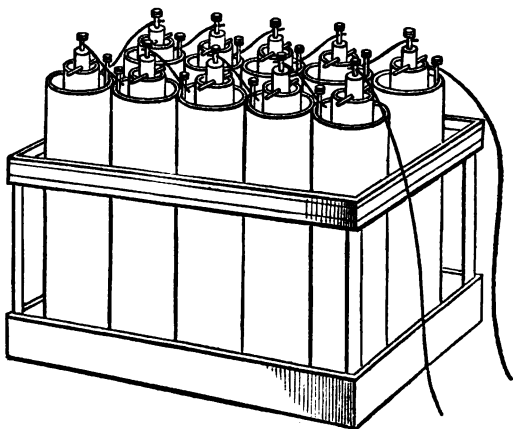
A single pair of this battery is represented in *fig. 54.* A, is a copper vessel; C, a porous cell, into which is inserted a cylinder of amalgamated zinc B; *a* and *b*, are binding screws for connecting the respective metals with others in the series, or for attaching conducting wires when a single pair only is to be used. The cell C, into which the zinc dips, is filled with diluted sulphuric acid (one of strong acid to about twenty of water); and the copper vessel A, is filled with a saturated solution of sulphate of copper. So long as the poles *a* and *b*, are disconnected, no action will take place; but the moment the circuit is completed by connecting the screws *a* and *b*, a very powerful action occurs; the inner surface of the copper vessel becomes gradually covered with a layer of pure copper, and the porous cell c, becomes charged with sulphate of zinc. This process tends to

*Fig. 54.*



deprive the solution of sulphate of copper of its copper, and to neutralise the sulphuric acid by the dissolution of the zinc ; in order therefore to sustain the action unimpaired, some crystals of sulphate of copper are placed upon a perforated shelf *c*, in contact with the solution.

*Fig. 55.*, shows the manner in which a series of these cells are connected so as to form a battery.



*Fig. 55.*

The advantages of this battery are as follows :—  
(1.) The solution of the zinc is kept apart from the copper by the porous cell. (2.) The hydrogen, instead of escaping, as in the ordinary batteries, combines with the oxygen of the oxide of copper, and precipitates pure copper upon the side of the copper vessel, and does not in the slightest degree affect the action of the battery. (3.) There are

no noxious fumes arising from the action of the battery. (4.) The amalgamation of the zinc, without at all affecting the production of electricity by the battery, prevents the zinc from being dissolved by the sulphuric acid when the battery is not in use, that is to say, when its poles are not united by a conductor; but the moment this union takes place, the zinc is attacked by the acid, just as if the mercury were not there, only the oxide that is formed does not adhere to the surface of the metal, which it would do if the zinc were not amalgamated, and would thereby tend to weaken the action of the battery. Plates of zinc are very easily amalgamated, by pouring mercury upon the zinc, and at the same time keeping rubbing it on the surface with a piece of chamois leather dipped in diluted sulphuric, which cleans the surface of the zinc, and thereby brings the mercury and zinc into combination.

**GROVE'S BATTERY.** This battery is constructed on the same principle as that of Daniell's, that is to say, the plates are acted upon by two liquids separated from each other by a porous earthenware partition. The pairs of plates are composed of amalgamated zinc *z*, and platinum foil *Pt*, plunged into a cell *A B C D*, composed of glazed porcelain or glass. The cell *A B C D*, is filled with diluted sul-

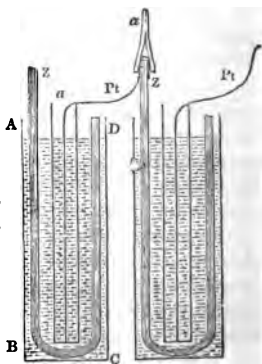



Fig. 56.

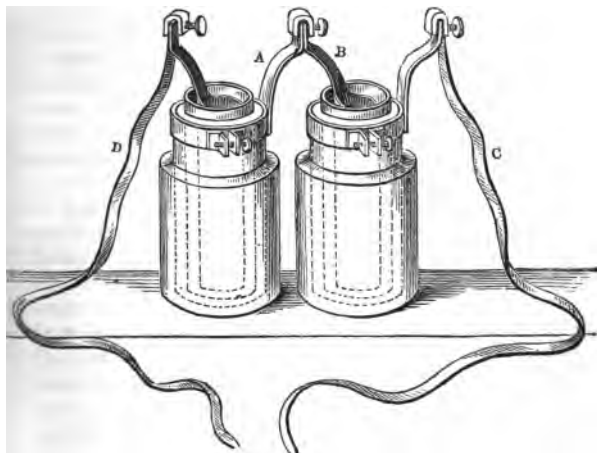
phuric acid, which acts directly upon the zinc; and the porous cell  $a$ , into which the platinum is plunged, is filled with nitric acid. The platinum plate Pt, is in metallic contact with the zinc of the succeeding cell, as shown at  $a$ ; and so on to the whole series of cells in the battery. As the power of these batteries is much increased by giving to the zinc plates a very large surface as compared with the surface of the platinum plates, the zinc plates are bent round the porous cell  $a$ , so that they form in each cell two vertical surfaces, united by a horizontal surface at the bottom.

When the poles of this battery are united, so as to bring it into action, the hydrogen, arising from the decomposition of diluted acid, does not attach itself to the platinum, but goes to change the nitric acid into nitrous acid; the oxide of zinc remains, as in Daniell's battery, in the cell of the diluted acid, without penetrating through the porous cell to the platinum, which consequently remains perfectly clean; this circumstance essentially contributes to keep up the power and constancy of the battery, which render it so valuable as a voltaic combination. After a time, however, the nitrous acid, which is constantly formed, acquires a high temperature and gives off deleterious fumes; when this takes place, the action of the battery should be arrested. This battery, for almost every purpose, is the most powerful that has yet been constructed. About half a dozen cells, with a platinum surface in each of ten square inches, will be found sufficiently powerful for performing all the most interesting experiments connected with voltaic electricity.

BUNSEN'S BATTERY differs from Grove's only in charcoal being substituted for the platinum. The



cells of this battery have the cylindrical form, represented in *fig. 57.*, in consequence of the carbon or charcoal being best made in the form of

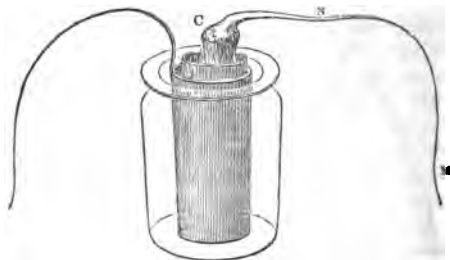


*Fig. 57.*

hollow cylinders. The strip of copper A B, shows how the zinc of one cell is united with the carbon cylinder of the succeeding cell; and so on. The figure also shows how the strips of copper C and D, forming the poles of the battery, are connected with the extreme cells of the battery.

Each charcoal cylinder, usually carries a collar of copper at its upper end for the purpose of fixing the connecting strip of copper to it; this copper stands above the glass vessel so as not to come in contact with the nitric acid; however, it is found

that, owing to the porous nature of the charcoal, the acid, to a certain extent, rises to the copper collar, and in time destroys its efficiency. The following contrivance, see *fig. 58.*, completely remedies this



*Fig. 58.*

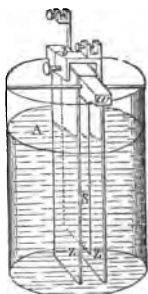
inconvenience: the charcoal cylinder C, is solid, and into its top is thrust a stout copper rod N, which is bent so as to be brought into contact with the succeeding zinc cell. To prevent the acid ascending to this copper rod, the top of the charcoal cylinder surrounding the wire is covered with a cement of wax.

It is almost unnecessary to say, that the charcoal cylinder in this battery is plunged into the nitric acid, filling the porous tube or cell, and that this porous cell is placed within the cylinder of amalgamated zinc, which is surrounded by the diluted sulphuric acid filling the glass jar or porcelain vessel.

[This battery is comparatively cheap, and the author can state, from his own experience, that it possesses great power, and is easily brought into action.]

**SMEK'S BATTERY.** In this battery the plates are acted upon by only one liquid, viz., diluted sul-

phuric acid (one part of acid to about seven parts of water.) *Fig. 59.* represents one of the cells of this battery. *A*, the earthenware cell filled with the diluted acid; *z z*, two vertical plates of amalgamated zinc, one on each side of the platinized plate of silver *s*; *w*, a bar of wood to which these plates are fixed; *b*, a binding screw which secures the zinc plates to the wooden bar. The connections are made, as usual, by means of the small binding screws shown in the figure. This forms a highly economical and efficient battery. Although its power may be less than Grove's battery, at the same time it is in many respects more convenient and agreeable for general use, especially for conducting experiments relating to electromagnetism.



*Fig. 59.*

#### VOLTAMETERS.

These instruments are used for measuring the power of a battery. There are three kinds of voltameters at present in use; one of them depends upon the decomposing power of the battery, another upon its heating power, and the third upon its magnetising power.

It has already been shown how the poles of a battery resolve water into its constituent gases, hydrogen and oxygen. Now it is presumed that this decomposing power of a battery is in proportion to its general power, or rather in proportion to the quantity of electric fluid developed by the battery. Now in the gas voltameters, represented in *figs. 60., 61., and 62.,* the quantity of gas

liberated by the poles of the battery in a given time is taken as the measure of the power of the battery, or, what amounts to the same thing, the

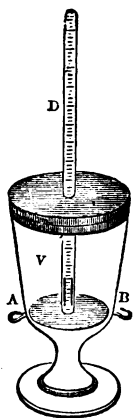


Fig. 60.

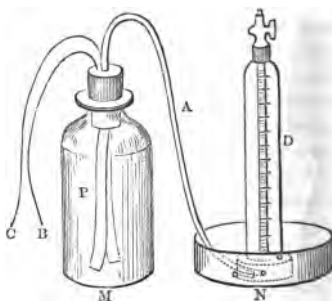


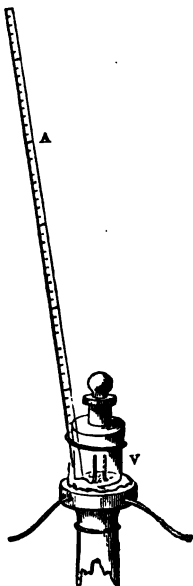
Fig. 61.

power may be measured according to the inverse ratio of the time requisite for liberating a given volume of the gas.

In *fig. 60.*, the platinum poles of the battery are placed vertically in a graduated glass tube D; very near to each other; the lower extremities A and B, come out at the bottom vessel V, containing the water, so that a connection may be readily made between them and the wires leading from the extreme plates of the battery. The two gases in this instrument are received in the same tube; they may, however, be received in separate tubes, as in the instrument represented in *fig. 37.*; but in

this case the platinum poles, being at a greater distance from each other, causes the decomposition to go on more slowly. When the battery has very great power, the gases are usually collected in a graduated receiver D, (*fig. 61.*) placed upon the pneumatic trough N; the decomposition of the water takes place in a bottle M, fitted up with a cork and bent tube A, for conveying the gases to the receiver D; the platinum poles or electrodes P, hanging near together within the bottle, are connected with the wires B and C, leading to the extreme plates of the battery.

*Fig. 62.* represents an eligible form of this apparatus, when the liberation of gas is very feeble. The quantity of gas is measured by the amount of displacement of the liquid. A graduated tube A, proceeds laterally from the lower part of the vessel v, wherein the decomposition of the water is carried on, so that as the



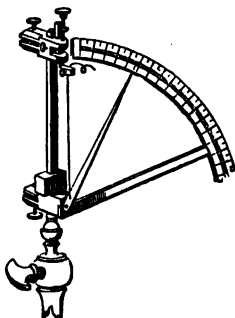
*Fig. 62.*

gases rise to the top of the closed vessel v, an equal volume of water is thrown up the tube A.

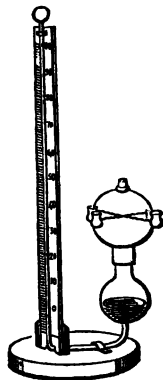
The three following voltameters depend upon the calorific effects of the battery.

*Fig. 63.* represents a voltameter, which is merely a slight modification of the common pyrometer. The platinum wire *a b*, forming a portion of the voltaic circuit, becomes powerfully heated and

expands, and allows the pointer *a d*, to fall; the graduation on the quadrant indicates the amount of expansion, and consequently the relative power of the battery.



*Fig. 63.*



*Fig. 64.*

*Fig. 64.* represents a still more sensible voltmeter, in which the platinum wire, forming a portion of the voltaic circuit, passes through the ball of an air thermometer; the expansion of the air by the heat of the wire, causes the liquid to rise in the vertical graduated tube; and so on.

The magnetic voltameter will be hereafter fully described.

## EFFECTS OF VOLTAIC ELECTRICITY.

## CHEMICAL EFFECTS.

THE chemical action of voltaic electricity upon different substances placed in the circuit, forms one of its most important and remarkable features. It has been shown that frictional electricity exerts a chemical action, but it is very feeble as compared with that which even small voltaic batteries exert.

One of the most remarkable facts connected with these decompositions is, that certain elements, into which the substances are resolved, always arrange themselves on the positive pole or electrode, and certain other elements always arrange themselves on the negative pole or electrode. Thus oxygen, chlorine, iodine, and the acids, always fly to the positive pole of the battery, and hydrogen, alkalies, oxides, &c., always fly to the negative pole; for example in the decomposition of water (see page 39.) the oxygen is accumulated in the tube placed over the positive pole, while the hydrogen is accumulated in that placed over the negative pole. This fact has led to the formation of a system of **ELECTRO-CHEMISTRY**. The respective poles are supposed to be in a contrary electrical state to the elements which they attract; hence, oxygen, chlorine, acids, &c. are negative elements, and alkalies, oxides, &c. are positive. Every chemical compound, therefore, consists of a negative element and a positive element, which are held united by the law of electrical attraction.

*Exp. 1. DECOMPOSITION OF WATER.* This is most elegantly performed by the apparatus described at page 39., but the following simple form of making the experiment is highly instructive.

Immerse a strip of amalgamated zinc, and a strip of clean copper into a glass of water slightly acidulated with sulphuric acid: so long as the metals are kept apart, no action can be observed, but the instant that the upper extremities of the metals are brought into contact the water is decomposed, numerous little bubbles of hydrogen collect round the copper, and the oxygen at the same time passes to the zinc and oxidises it.

*Exp. 2. DECOMPOSITION OF NEUTRAL SALTS.* Fill the two tubes of the apparatus represented in *fig. 37.* page 39., with a solution of sulphate of soda, or any other neutral salt, coloured blue with tincture of violets; then when the battery is in action, the acid will be attracted to the positive electrode, and will render the liquid in the tube red, and the alkali will be attracted to the negative electrode, and will tinge the liquid in the tube green; transpose the poles and the effects will be reversed.

*Exp. 3. TO PRECIPITATE A METAL FROM THE SOLUTION OF A METALLIC SALT.* *Fig. 65.* represents a simple piece of apparatus for producing this decomposition. *a*, is a glass tube about an inch in diameter, having a piece of bladder tied over its lower extremity, and suspended in a large glass vessel *b*; pour a solution of acetate of lead, (sulphate of copper, nitrate of silver, &c., will answer the purpose) into the glass tube *a*; fill the outer vessel with diluted sulphuric acid; into the solution of lead immerse



*Fig. 65.*

a platinum wire *p*, and into the diluted sulphuric acid plunge a strip of amalgamated zinc *z*, in metallic contact with the platinum; then a voltaic circuit will be formed, consisting of two metals and two exciting fluids; the acetate of lead will be decomposed, the metallic lead will be attracted to the platinum, and the acid to the zinc.

The metallic vegetations called *the lead tree*, &c. depend upon the voltaic action.

*Exp. 4.* Connect the tin-foil plate *G*, with the copper pole of a small battery, and the metal plate *D*, with the zinc pole of the battery. Lay a piece of white blotting paper, soaked in a diluted solution of hydrochloric acid and prussiate of potassia, upon the plate *D*; draw a number

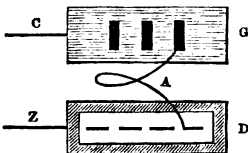


Fig. 66.

of strokes with a brush dipped in varnish across the plate *G*, as shown in *fig. 66.*; take a bent wire *A*, and connect the two plates with it; move the wire from end to end; then the electro circuit will be complete whenever the wire connects the metallic foil and the damp paper, and the circuit will be broken at those parts where the wire passes over the varnish; the solution on the paper will be decomposed at the former parts, but will remain unchanged at the latter parts, as will be shown by the deep blue marks formed upon the paper by the decomposition of the prussiate of potash.

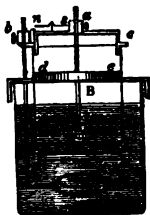
This experiment illustrates the principle on which the **COPYING ELECTRIC TELEGRAPH** is constructed.

*Electrotyping.*

The decomposition and reduction of metals, in a state of solution, by the voltaic battery, has led to some important discoveries in the arts, such as electrotyping, electroplating, &c.

The experiment given in connection with *fig. 49.* page 42. is a familiar example of electroplating; electrotyping depends upon the same principle.

*Fig. 67.* represents a very simple contrivance for obtaining small electrotype casts. *A*, is a glass vessel in which the mould from which the cast is to be obtained, is placed. *B*, is a glass tube suspended within the vessel *A*, by means of a metallic ring *d e*, to which are fixed three strips of metals. The lower end of this tube *m n*, is closed by tying a piece of bladder over it. The strip of brass *b c*, has two binding screws *b* and *a*, by which the wires *a z*, and *b k*, are secured; the lower



*Fig. 67.*

extremities of these wires carry the substances *z* and *k*, which act as the electromotors or voltaic plates constituting the simple battery. *z*, is an amalgamated zinc plate, suspended within the tube; *k*, is the body from which the cast is to be taken, laid on the spiral shaped-extremity of the wire *b k*; the model is the negative electromotor, and *z*, the positive electromotor. The large glass *A*, contains a concentrated solution of sulphate of copper; this is always kept in a saturated state by having crystals of sulphate of copper suspended in it; the tube *B*, is filled with diluted sulphuric acid; the liquids should stand at the same level in

both vessels. According to this arrangement, the electric current passes from the zinc *z*, to the mould *k*; and pure metallic copper is deposited upon the surface of the mould, and in time forms a complete cast of the surface.

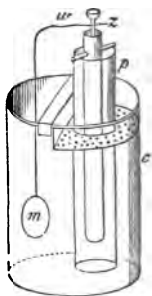
The following particulars should be attended to in making electrotype casts. The surfaces of the originals should be good conductors, and they should not contain any substances which would be acted upon by the sulphate of copper. The model may be of gypsum, wax, or any similar non-conducting substance, provided the surface of the model be covered with a metallic coating: plumbago dust or bronze powder, laid on with a camel's hair brush, forms a very good coating. A wax impression should be first slightly moistened with alcohol, and then the black lead should be rubbed over it with a stiff brush; the copper wire should then be warmed and pressed into the margin of the wax, the connection between the wax and wire should then be made with the black lead. A coating of wax dissolved in turpentine will protect any part of a coin from any metallic deposit. In every electrotype cast the elevated portions of the original will be depressed, and *vice versâ*; in order therefore to obtain exact fac-similes of the original, the first cast must be used as a matrix on which the coating of copper must be thrown by the electrotype process.

*Fig. 68.* represents a more convenient arrangement. *z* is the amalgamated zinc rod, suspended in the porous cell *p*, which contains the diluted sulphuric acid; *c*, the glass or earthenware vessel containing the solution of sulphate of copper; *w*, the copper wire connected with the zinc by a

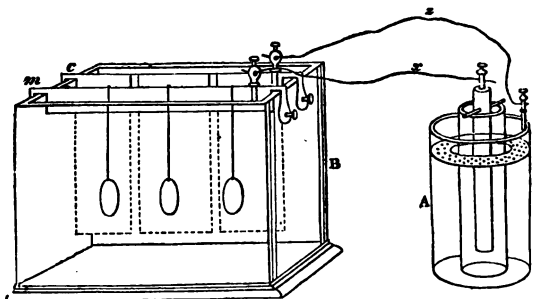
binding screw, and carrying at its lower extremity the seal or mould *m*.

*Fig. 69.* represents another arrangement, where the current is generated in a distinct battery *A*; *B*, is a distinct vessel for conducting the electrotype process. *m*, is a metal rod for supporting the moulds, and *c*, another rod supporting copper plates, which form the positive electromotors; *x*, connects the moulds with the zinc in the battery, and *z*, connects the copper plates with the copper plates of the battery.

The vessel *B*, contains two parts of saturated solution of sulphate of copper, and one part of sulphuric



*Fig. 68.*



*Fig. 69.*

acid diluted with about seven parts of water. The action which takes place is simply as follows: the copper is consumed from the plates *c*, and deposited on the moulds *m*; so that the copper solution in the vessel *B*, remains unchanged in its strength from the commencement to the close of the process.

## ELECTROPLATING EXPERIMENTS.

*Exp. 1.* Place a small plate of clean platinum foil in a saucer, and pour over it a solution of sulphate of copper covering it to the depth of about a sixteenth of an inch; touch the platinum plate with a pointed strip of bent zinc, the other end of which is kept in the liquid; different coloured rings of metal will be formed upon the platinum plate.

*Exp. 2.* The brilliancy of the depositions will be much increased by using a constant battery of three or four pairs of cells.

## PROTECTION OF METAL PLATES BY VOLTAIC CURRENTS.

Voltaic currents not only affect combinations and decompositions, but they may also be employed for impeding or arresting certain decompositions which would otherwise take place by the ordinary laws of chemical affinities. Thus for example, Davy protected the copper bottoms of ships from the corrosion of the salt water, by connecting plates of zinc with the copper sheathing. In order to protect a metal from the chemical action of an acid or a saline solution, it is only necessary to combine the metal with some other metal in the fluid, which shall act as the positive electromotor.

*Exp. 1.* Place a copper plate in a saucer; pour some diluted sulphuric acid upon it; then the metal will be violently acted upon by the acid; now touch the copper with a strip of zinc, and the action on the copper will be instantly arrested; the action will now be transferred to the zinc, and

the copper will remain unaffected by the acid, until the whole of the zinc be dissolved.

#### LUMINOUS AND HEATING EFFECTS OF VOLTAIC ELECTRICITY.

The most brilliant of all the effects of voltaic electricity is the arch of electrical light evolved between two charcoal points. This phenomenon may be exhibited with about a dozen pairs of



*Fig. 70.*

Grove's or Bunsen's battery. This experiment may be most conveniently performed by fixing charcoal points (pieces of graphite answer best) to the rods of a universal discharger. The poles of the battery are respectively connected with the extremities of the rods, as shown in *fig. 70.*, where the arch A B, represents the form of the voltaic light. The points must be first brought into contact with each other, and then gradually withdrawn until the arch attains its most brilliant appearance; the length of the arch of course varies with the power of the battery; that is, with batteries of average power, from three quarters of an inch to about an inch and a half. This arch of flame is not produced by combustion, for it may be exhibited with equal brilliancy in a vacuum, and even takes place under water.

The intense heat of this electric arch will ignite the most refractory substances.

*Exp. 1.* Amalgamate the ends of the polar wires; bring them near together, while the battery is in action; a white starlike spark will be



seen accompanied with a crackling noise similar to the emission of a feeble spark of frictional electricity.

*Exp. 2.* The spark obtained from these amalgamated points may be seen under water, or in the flame of a candle.

*Exp. 3.* Immerse one of the wires into mercury, and bring the end of the other wire near the surface of the fluid; a spark is emitted just before the wire touches the mercury, leaving a small black speck upon its surface.

*Exp. 4.* Coat the ends of the polar wires with soot, by holding them for a short time in the flame of an oil lamp; the sparks obtained from these coated wires will be much stronger and brighter.

The power of a voltaic battery, as we have already shown, is roughly estimated by the heat which it produces in a given conducting wire. The temperature to which a conducting wire will be raised by a battery, depends upon the length and thickness of the wire, as well as upon the nature of the metal, whether or not it is a good or a bad conductor of electricity. Short fine wires become most heated, and of all metallic wires, platinum, being the worst conductor of electricity, becomes most powerfully heated by conducting the electric fluid.

The calorific effect appears to depend more upon the size of the plates than upon the number of pairs; that is to say, it depends upon the quantity of the electric fluid evolved rather than upon its intensity or tension.

The calorific effects of the voltaic battery may be most conveniently shown, by stretching the wires to be heated between the extremities of the rods of the universal discharger (see *fig. 70.*).

*Exp. 1.* To show the heating power of a battery. Stretch a piece of fine steel wire between the poles of the battery; the wire, if it is not too long, will instantly become powerfully incandescent. If on the first trial, the wire only presents a dull heat, gradually reduce the length of the wire, until it glows with a white heat; reduce the length of the wire a little more, then it will be first fused, and then ignited.

The same experiment may be performed with platinum, or silver wire.


*Exp. 2.* Æther, alcohol, phosphorus, gunpowder, &c. may be readily ignited by making the hot platinum connecting wire to pass through them, or to touch some portion of them.

*Exp. 3.* If the platinum wire be conducted through a small portion of water, it will speedily boil.

#### PHYSIOLOGICAL EFFECTS OF VOLTAIC ELECTRICITY.

The relation between voltaic action and the nervous system of animals, was very carefully investigated at a very early stage of the history of voltaic electricity.

The peculiar nature of this relation is explained at page 37. of this work, when a small battery is employed. But with large batteries the effects are truly surprising. Dr. Ure thus describes his experiments upon the body of a full grown man, fifteen minutes after death. Upon applying one of the polar wires to the forehead, and the other to the heel, every muscle in his countenance was simultaneously thrown into fearful action; rage, horror, despair, anguish, and ghastly smiles united their



hideous expression in the murderer's face. At this period several of the spectators were forced to leave the apartment from terror and sickness, and one gentleman fainted.

The physiological effects of voltaic electricity appear to depend upon intensity, rather than upon quantity, that is to say, upon the number of pairs in the battery, rather than upon their extent of surface.

The effect of the voltaic shock is much increased by attaching copper cylinders to the extremities of the conducting wires, and also by dipping the hands, by which the shock is received, in water slightly acidulated.

The magnetic effects of voltaic electricity are so various and interesting, that they have been treated as a distinct branch of electrical science, called *Electro-Dynamics*.

## ELECTRO-DYNAMICS.

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### ELECTRO-MAGNETISM.

It has already been shown (*Exp.* 9. p. 44.) how a steel needle may be magnetised by passing a voltaic current through a wire helix. When a helix is wound to the right, or in the direction of a corkscrew, it is called a **RIGHT-HANDED helix**, as shown in *fig.* 71., and when the helix is wound in



*Fig.* 71.



*Fig.* 72.

the contrary direction, that is, to the left, it is called a **LEFT-HANDED helix**, as shown in *fig.* 72. Helix wires should be formed of copper wire, covered with silk, for the purpose of insulating them.

*When a needle is magnetised by a current passing through a right-handed helix, or a corkscrew helix, the south pole of the needle is always at the extremity through which the currents enter, that is to say, at the extremity that is in connection with the positive electricity. On the contrary, when a needle is magnetised by a left-handed helix, the north pole is at the extremity which is in connection with the positive electricity.*

These facts are in exact accordance with Ampère's theory of magnetism (see p. 35.); for the

electric current moves round the magnetic bar in precisely the same manner as the magnetic current is supposed to do in that theory, thereby showing that the electric current which induces the magnetic condition is equivalent to the magnetic current upon which the ordinary magnetic condition is supposed to depend.

Let *s N. fig. 73.*, be a right-handed helix, that is, a corkscrew helix, through which the electric current enters at *s*, and passes out at *N*; then, from what has been said, the helix will become a magnet, having the extremity *s* for its south pole, and *N* for its north pole. This may be tested experimentally by using *De la Rive's floating battery*. The extremities of the helix are connected with zinc and copper plates *z* and *c*, fixed in a piece of cork, so as to make the whole apparatus to float in a strongly acidulated liquid. This float battery, like the floating needle, will place itself in the north and south direction of the needle; the extremity *s*, through which the current enters, will be directed to the south.

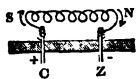


Fig. 73.

The Author has found the following form of this apparatus to be very convenient in practice.

*B* is a deal-board, having two concentric grooves *E* and *F* cut in it, and filled with mercury; the wires *N* and *M* connect the mercury in these grooves with the binding-screws

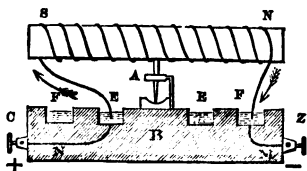


Fig. 74.

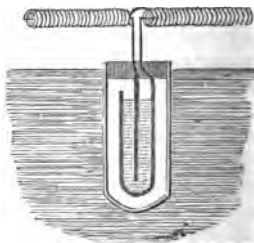
*c* and *z*, to which the poles of the battery are at-

tached; *s N* is a corkscrew helix surrounding a soft bar of iron; one extremity of the wire dips into the mercury of the groove *F*, and the other into that of the groove *E*; the soft iron bar, with its helix, turns upon the pivot *A*. When the positive pole of the battery is fixed to the binding-screw *C*, and the negative pole to the binding-screw *Z*, the helix, with its soft iron bar, becomes an actual magnetic needle, and will settle itself in the direction of the magnetic meridian, the extremity *s* being directed to the south, and the other extremity *N* to the north.

If the soft iron bar be taken away, and a steel needle be inserted in its place, the needle will be magnetised, having the extremity towards *s* a south pole, and the extremity towards *N* a north pole.

*Fig. 75.* represents another form of the floating battery, where the copper and zinc plates are immersed in a glass tube, filled with the diluted sulphuric acid, and the whole is made to float in a vessel of water.

Electro-magnets of immense power may be formed by voltaic helices.



*Fig. 75.*

*The Electro-magnet, or soft iron Horse-shoe Magnet.*

*Fig. 76.* represents an electro-magnet; *M* is the soft iron bent in the form of a horse-shoe magnet; *P* and *N* are the extremities of the helix of covered

copper wire, surrounding the bar in the manner just described; *K* is the keeper of the magnet, from which a heavy weight may be suspended to show the power of the magnet. When the extremities, *P* and *N*, are connected with the poles of a single pair of any of our constant batteries, the soft iron instantly becomes a very powerful magnet, capable of supporting a weight of 1 cwt. to about 1 ton.

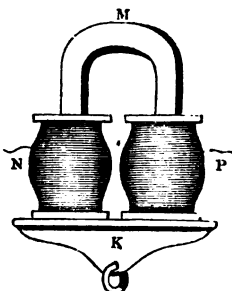


Fig. 76.

The moment the connection is broken, the magnet loses its power. The wire, intended to form the coil, is cut into several portions, and is coiled separately on the iron, and then all the corresponding extremities are collected into parcels, which are soldered to a thick wire which communicates with the pole of the battery. By this arrangement, the current is divided into a series of short branches, which, collectively, communicate with the poles of the battery by a short strong wire; this gives energy to all the coils, and thereby increases the power of the electro-magnet.

These temporary magnets have been called *electro-magnets*, to distinguish them from permanent steel magnets, and *electric helices* just described.

### *Rotating Magnets.*

The rotating magnet, invented by Dr. Richie, is represented in *fig. 77*. In this instrument a permanent rotatory motion is given to an electro-magnet, *c*, upon a vertical pivot, by means of the al-

ternate attraction and repulsion of the poles, *N* and *s*, of a permanent horse-shoe magnet. In order to produce this continuous rotation, it is requisite that the poles of the electro-magnet should be reversed at every time they pass the poles of the permanent magnet; this is effected by a very simple and elegant artifice: *a b* is a wooden cup of mercury, divided into two compartments by a bridge or partition of wood, in a line with the poles *N* and *s*, whose upper edge is a little below the exterior edge of the cup; so that when the two compartments are filled with mercury, the cohesion of the particles of the fluid causes it to stand a little higher than the level of the top edge of the partition; the two extremities of the helix dip a little into the mercury without reaching to the level of the top of the partition, so that the electro-magnet may freely revolve upon its vertical pivot; the mercury in one of the compartments is connected with the positive pole of a small battery, and the other compartment with the negative pole; by this contrivance the poles of the electro-magnet are reversed at every time the dipping-wires cross the partition, and, consequently, if the poles of the permanent magnet attract the poles of the electro-magnet in any given position, they will be repelled the moment the dipping-wires have crossed over the partition, and thus the continuous rotation is sustained.

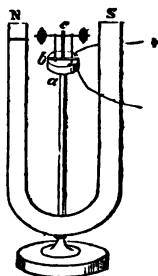


Fig. 77.

The following is a brief description of a rotatory magnet invented by the Author some twenty years ago, and employed by him in an extended form as a

magnetic engine, capable of yielding about a quarter of a horse-power. The contrivance in this form was described in the "Mechanics' Magazine" for the year 1840.

N S is the electro-magnet, turning upon a horizontal axis A B; N F and S E are the terminal wires of the coil; each of them forks off into two branches, F H, F J, and E K and E G; the extremities of the wires are connected with metal

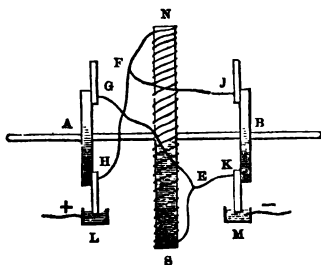
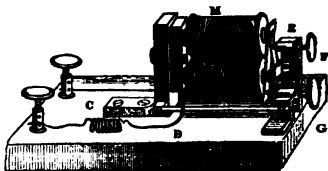


Fig. 78.

segments, H, J, K, and G, attached to the ivory wheels A and B, fixed to the common axis A B; the circumferences of these segments are placed concentric with the axis of motion, and their edges dip into mercury placed in the cups L and M, which are connected with the poles of the battery: by this contrivance the poles of the electro-magnet are changed when one pair of segments passes out of contact, and another pair comes into contact, with the mercury in the cups. The opposite poles of a permanent magnet are placed in a line with the electro-magnet when its position corresponds with the change of its polarity, as in the case of Richie's rotating magnet.

*Contact-breakers.—Telegraphic Alarm-bell.*

The two foregoing pieces of apparatus show how the poles of an electro-magnet may be reversed by changing the direction of the voltaic current. The contrivance represented in *fig. 79.*, called a contact-breaker, shows with what rapidity an electro-magnet can acquire and lose its magnetism.

*Fig. 79.*

**M** is a small electro-magnet, the armature of which, **E**, is capable of oscillating between the two poles of the magnet and a stop at its back, against which it is pressed by a spring. The conducting-wire **D** coils round the lower branch of the magnet, as shown in the figure, and the other conducting-wire, **C**, is attached to the stop, and then a wire passes from the foot of the oscillating armature to the extremity of the coil passing round the upper branch, **M**, of the electro-magnet; so that the electric current is complete when the armature is in contact with the stop, and it is broken when this contact is destroyed. The consequence of this arrangement is, the electro-magnet attracts the armature, which breaks the circuit, and the magnetism instantly ceases; then the armature, being pressed back by the spring, returns and strikes the stop, which again completes the circuit and renews the magnetism; the armature is again attracted by the magnet, and so on with great rapidity. The ad-

justing screws, F and G, enable the operator to regulate the rapidity of the strokes.

*Telegraphic alarum-bell.* To form this instrument into an alarum-bell, it is only requisite to fix a hammer to the top of the armature E, and to place a bell within the striking distance.

*Instruments for measuring the Force of Magnets.*

1. *Method of contact.*—The following is a simple contrivance for estimating the suspensive force of an electro-magnet. N J S is the electro-magnet ; p

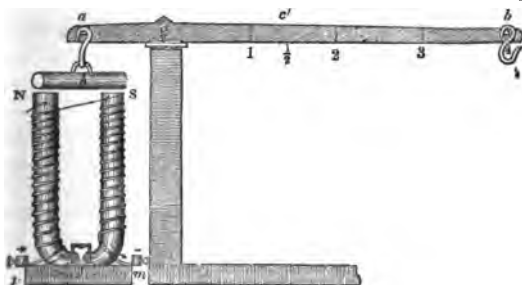


Fig. 80.

and m the binding-screws to which the poles of the battery are fixed ; A the feeder or armature, suspended from the extremity a of a graduated lever a b, turning on a fixed centre or fulcrum c ; h, a sliding-hook, to which a scale-pan with weights may be attached. The weights, put in the scale-pan, necessary for breaking the contact of the feeder A, give the data for calculating the force of the magnet, on the simple principle of the lever of the first kind.

2. *Method of vibrations.*—The oscillations of a magnetic needle before it settles in its north and south direction, follow the same law as the vibrations of the pendulum. The directive force of a magnetic needle, therefore, may be measured by the number of oscillations that it will make in a given time, when drawn a little to one side of its magnetic meridian. When the same needle is employed to determine the directive force at two different places on the earth, this directive force varies as the squares of the number of vibrations performed in a given time.

The vibration of the needle is also employed to determine the intensity of the different points in a magnetic bar. In this case it is necessary that an allowance should be made for the directive force of the earth.\*

\* By *Ex. 7.* and *8.*, page 252. *Tate's Mechanical Philosophy*, we have

$$g = \frac{\pi l}{t^2}, \text{ and } n = \frac{N}{\pi} \sqrt{\frac{g}{l}}$$

when  $g$  is put for the attractive force of the terrestrial magnetism,  $l$  the length of the pendulum,  $t$  the number of seconds in each vibration,  $n$  the number of vibrations performed in a given time  $N$ .

Now when  $l$  and  $N$  remain constant for any series of experiments, we have from the first

$$g \propto \frac{1}{t^2} \text{ or } t \propto \frac{1}{\sqrt{g}}$$

and from the second,

$$g \propto n^2,$$

that is to say, the intensity of terrestrial magnetism at different places on the earth's surface, as applied to magnetic needles, is inversely as the squares of the times of their vibra-

According to the experiments made by Coulomb, the attractive forces of the different points in a long magnetic bar, as estimated from the centre of the bar, increase in a geometrical progression as the distances from the centre increase in arithmetical progression.

#### TO MAGNETISE STEEL BARS BY THE ELECTRO-MAGNETIC COIL.

The simplest way of doing this is to coil a very stout copper wire covered with silk round a paste-

tions, and directly as the squares of the number of oscillations performed in a given time.

Again, for the case of the magnetised bar, let  $g_1, g_2, g_3$ , be put; for the total action exerted upon it when successively made to vibrate before three consecutive points of the bar;  $n_1, n_2, n_3$ , the number of oscillations made by the needle in the given time  $N$ ; then

$$n = \frac{N}{\pi} \sqrt{\frac{g}{l}}, \text{ and } n_1 = \frac{N}{\pi} \sqrt{\frac{g_1}{l}},$$

$$\therefore \frac{g_1}{g} = \frac{n_1^2}{n^2};$$

similarly,

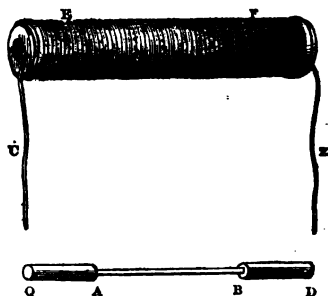
$$\frac{g_2}{g} = \frac{n_2^2}{n^2}, \text{ and } \frac{g_3}{g} = \frac{n_3^2}{n^2}.$$

By combining these three equations we readily get,

$$\frac{g_1 - g}{g_2 - g} = \frac{n_1^2 - n^2}{n_2^2 - n^2}, \text{ and } \frac{g_1 - g}{g_3 - g} = \frac{n_1^2 - n^2}{n_3^2 - n^2}.$$

Now  $g_1 - g, g_2 - g, g_3 - g$ , represent the magnetic forces residing in each of the three points of the magnet; these forces may be compared with each other, when we have determined by experiment the values of  $n, n_1, n_2, n_3$ .

board tube, about 18 inches long and 2 inches diameter. The bar, A B, to be magnetised is placed between two soft iron cores, A Q and B D, made exactly to fit the interior of the paste-board tube E F. The whole is placed within the tube, and the extremities, C and Z, of the helix are connected



*Fig. 81.*

with the poles of the battery: in a short time the steel bar, A B, will be magnetised to saturation.

## ON THE ACTION OF ELECTRIC AND MAGNETIC CURRENTS.

IN addition to the magnetic effects of electrical currents, which have just been noticed, the following general laws of electrodynamics have been established.

### *General Laws of Electrodynamic Action.*

1. Every metallic conductor through which an electric current passes, acts on magnets suspended freely, and shows magnetic properties.

2. Electric currents exert on each other influences like those which they exert on magnets.

3. A magnet acts on an electric current precisely as another current would do.

4. Electric currents in conductors in like manner excite such currents.

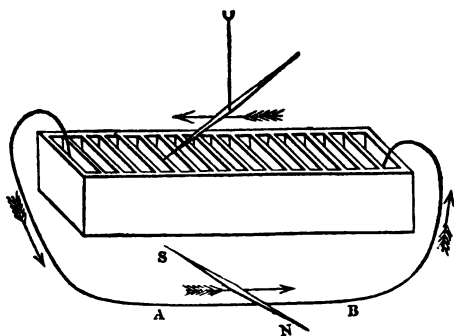
5. Magnets can, in like manner, excite electric currents, and the other electric influences dependent on them.

It must be observed, that the condition essential to these effects is, that the electric fluid must be in a state of motion, that is, it must be in the form of a continuous current, or, in other words, it must be in the condition which is called *dynamic*; there is no action when the electricity is in the *static* or *tension* state.

### ACTION OF ELECTRIC CURRENTS ON THE MAGNETIC NEEDLE.

*Oersted's Experiment.*—Place the conducting

wire, A B, of a battery in the direction of the magnetic meridian, viz., B towards the north and A towards the south, as shown in *fig. 82.* ; suspend a



*Fig. 82.*

needle S N *over* the conducting wire A B, and the north pole N will be deflected to the east; suspend the needle *below* the conducting wire A B, and its north pole will be deflected to the west.

The needle, therefore, endeavours to assume a position perpendicular to the direction in which the electric current flows.

Ampère represented the action of the electric current on a magnetic needle under a form which is easily remembered. "We have only to conceive a man lying down in the portion of the circuit under consideration, in such a manner that the current enters by his feet, and goes out, consequently, by his head: furthermore, we have but to conceive that this man has always his face turned towards the needle, so as to look at it; then the action is always found to be such that the north

pole of the needle is deviated to the left of this man. This formula comprehends all possible cases."

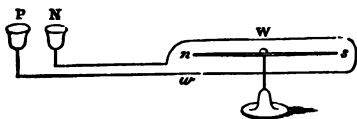
It is easy to see that the positive current, coming from the positive pole of the battery, passes along the conductor and arrives at the negative pole, and returns through the plates of the battery to the positive pole; so that the current has a different direction in the two parallel portions of the circuit, as shown in *fig. 82*.

All these effects are perfectly in accordance with the theory of magnetic action, explained at p. 35. The needle seeks to place itself at right angles to the direction of the current, on the principle that the electric current in the magnet seeks to place itself parallel to the current in the wire.

### *Galvanometers. The Electric Telegraph.*

We have explained the construction of certain voltmeters or galvanometers depending upon the calorific and chemical effects of the voltaic current; but the most perfect instrument of this kind is that which depends upon the magnetic effects of the current.

The most simple magnetic galvanometer is represented in *fig. 83*. A magnetic needle, *ns*, is suspended between two conducting parallel wires, *w* and *w'*, terminating in the mercury cups, *P* and *N*. The conducting wire is placed in the direction of the magnetic meridian, so that the needle has the same direction as the wires. When the poles of the battery are in-

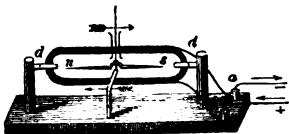


*Fig. 83.*

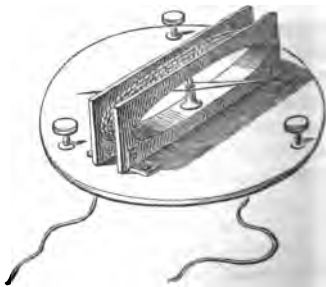
serted in the cups, P and N, the needle is deflected after the manner described in the foregoing section. According to this arrangement, the conducting wire above the needle, as well as the wire below it, tends to deflect the needle in the same direction, so that the double wires exactly double the amount of deflection. The angle of deflection gives us a rough mode of estimating the quantity of voltaic fluid evolved by the battery.

The *Electric Telegraph* consists of two or more galvanometers, by means of which telegraphic signals may be transmitted from one railway station to another. The number, order, &c., of the oscillations of the needle, being associated with certain letters and words, enable the operator at one station to communicate messages to the person at the other station.

But, instead of bending the wire round the needle once, if we bend it twice, thrice, or any number of times, we must obviously increase the deflecting power in the same ratio. This construction is adopted in the galvanometer represented in *fig. 84.*; where *n s* is the needle surrounded by a series of coils of covered silk wire, *a d d.* This instrument has been called the *galvanometer multiplier.*



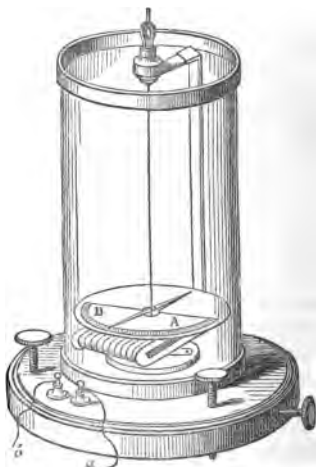
*Fig. 84.*



*Fig. 85.*

*Fig. 85.* represents a more elegant form of the instrument; where the coil of wire is wound round a wooden frame fixed upon a stand, and provided with binding-screws.

*Nobil's galvanometer multiplier*, represented in *fig. 86.*, consists of an *æstatic needle* (see p. 34.), suspended by a filament of untwisted silk, one of the needles being placed within the conducting coil, the other without it; so that the current of electricity tends to deflect both needles in the same direction, thereby giving a double power to the instrument. The whole of the coil, together with the needle and its thread of suspension, are covered with a glass shade; *a* and *b*, fixed to the binding-screws, are the wires proceeding from the poles of the current, whose power is to be determined by the instrument; the extremities of the wire coil, of course, terminate in these binding-screws.



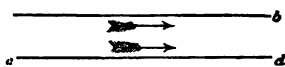
*Fig. 86.*

#### ACTION OF ELECTRIC CURRENTS ON EACH OTHER.

Ampère discovered the following laws, according to which electric currents act upon each other:

1. *Parallel currents attract each other when they flow in the same direction.*

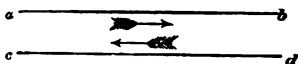
Thus the parallel wires, *a b* and *c d*, represented in *fig. 87.*, transmitting currents in the same direction, attract each other.



*Fig. 87.*

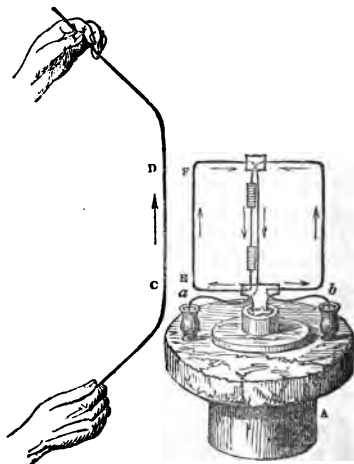
2. *Parallel currents repel each other when they flow in contrary directions.*

Thus the parallel wires, *a b* and *c d*, represented in *fig. 88.*, transmitting contrary currents, repel each other.



*Fig. 88.*

These laws are perfectly in accordance with the theory of magnetism explained at p. 35.



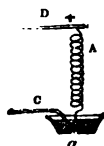
*Fig. 89.*

In order to establish these laws by experiment, the floating battery represented in *fig. 89.* may be employed. This battery consists of a pair of plates, viz., platinum and amalgamated zinc, fixed to a cork float *A*, and having its poles in connection with the cups *a* and *b*; the wire frame proceeding from these cups conducts the current as represented by the arrows in the figure; the whole of this floating battery is placed in a vessel containing diluted sulphuric acid, which acts as the exciting fluid. To one of the vertical branches, *E F*, we present a parallel wire, *C D*, traversed by a powerful current of electricity; then when the currents flow in the same direction, the wire *E F* with its floating battery is attracted by the wire *C D*; and, on the contrary, when the current in the wire *C D* flows in a contrary direction, the floating battery is repelled.

The same laws hold true with respect to angular currents, or those currents whose directions are inclined to each other; the form of expression in this case being simply, that *currents which are directed to the same point, or which proceed from the same point, attract each other, and vice versâ, as before.*

#### VARIOUS MOTIONS PRODUCED BY THE MUTUAL ACTION OF MAGNETS AND CURRENTS, AND CURRENTS UPON EACH OTHER.

The oscillating electrical spiral, represented in *fig. 90.*, affords a beautiful illustration of the attraction of parallel currents. A fine flexible copper spiral wire *A*, is suspended from the extremity of a conductor *D*, proceeding from the positive pole of the battery; the lower extremity of this spiral dips slightly into a cup of mercury *a*, in which is placed the extremity of



*Fig. 90.*

the wire *c*, leading from the negative pole of the battery. When the current is complete, the spiral vibrates longitudinally; for at every contraction the current is broken, and then the weight of the wire causes its extremity to sink again into the mercury, and thus a continuous oscillation is sustained.

It has been shown that *a fixed or closed current exerts a tangential force upon the pole of a magnet which is free to move*: thus let *A B*, in *fig. 91.*, re-

present the direction of the fixed current, and *N* the pole of a magnet, free to obey the impulse;

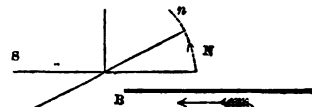


Fig. 91.

then the north pole *N* is impelled in the tangential direction *N n*, that is to say, in a direction perpendicular to the direction of the current, *A B*.

In like manner, since action and reaction are equal and contrary, *a pole of a magnet exerts a tangential force on a current which is free to move*;

thus the pole *N* of a fixed magnet (see *fig. 92.*) will impel the free wire *A B* conducting a current in the tangential direction *B a*.

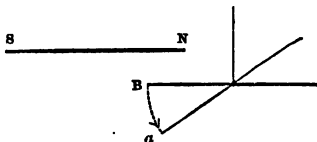


Fig. 92.

These results are generally represented in *fig. 93.*, where *N* represents the north pole of a magnet, *O* the section of the conductor of a descending electric current perpendicular to the plane of the paper; then the action of *c* upon *N* tends to move it in the

direction  $Nn$ , and the reaction of the pole  $N$  upon the wire  $C$  tends to move it in the contrary direction  $Cc$ . If, therefore, the pole  $N$  be free to move round the wire  $C$ , the tangential line  $Nn$  will be the direction of the motion; and if the conducting wire  $C$  be free to move round the pole  $N$ , the tangential line  $Cc$  will be the direction of the motion.

The following rotatory motions depend on these principles.

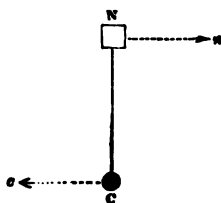


Fig. 93.

*To make the pole of a magnet,  $N$ , revolve round a fixed electric current  $C$ .*

This was first effected by Faraday in the following manner:—A small magnet  $N$ , is fixed to the lower part of a vessel  $V$ , by means of a silk thread; the vessel is filled with mercury nearly to the top of the magnet;  $C$  is a conducting wire dipping into the mercury, and  $Z$  is another conductor communicating with the mercury at the bottom of the vessel. Now when the electric current is established, by connecting the extremities of the wires,  $C$  and  $Z$ , with the opposite poles of the battery, the pole  $N$  of the magnet revolves round the conducting wire  $C$ . The ends of the wires should be amalgamated to ensure metallic contact. If the current is descending, that is, if  $C$  be connected with the positive pole of the battery, and if  $N$  be a north pole, its motion round the wire will be direct, that is, in the direction of the hands of a watch; and so on *vice versâ*.

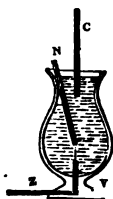


Fig. 94.

*To make a moveable wire, A B, traversed by a current, revolve round the pole, N, of a fixed magnet.*

Here the wire A B is suspended from the wire c by a loop, and dips into the mercury in the vessel v; when the circuit is established, by connecting the wires, c and z, with the respective poles of the battery, the conducting wire revolves round the pole, N, of the magnet.

If the current be descending, and N be the north pole of the magnet, the rotation will be direct.

These two rotations may be exhibited in one piece of apparatus, as represented in *fig. 96.*, where *m* represents the revolving small magnet, which is best made with a sewing needle; *f p*

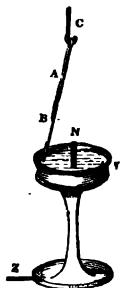


Fig. 95.

the revolving wire; *c* the positive pole of the battery; and *z* the negative pole. When the north poles of the magnets are both turned upwards, the rotations take place in the directions of the arrows, as shown in the figure.

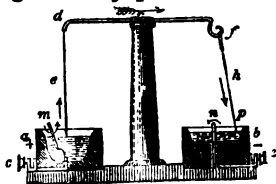


Fig. 96.

Reverse the direction of the electric current, and the rotations will be reversed.

*Ampère's rotation of a current about the pole of a magnet.*

On the two poles, N and S, of a permanent horse-

shoe magnet, are placed two cells of copper (*a c c e n* on N, and *e z z a n* on S); *b d*, *b d*, are copper wires attached to cylinders of amalgamated zinc, which dip into the diluted sulphuric acid, filling the cells; these zinc cylinders turn on pivots at *s s*; the zinc cylinders revolve round the respective poles of the magnet in contrary directions, that is, in the directions indicated by the arrows.

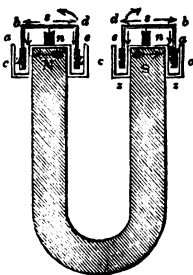


Fig. 97.

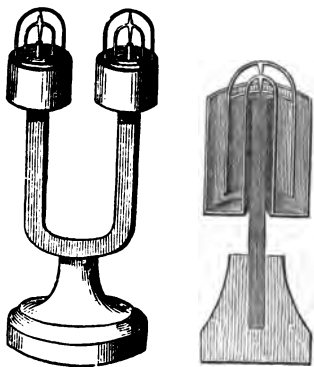


Fig. 98.

*Fig. 98.* represents a slight modification of the foregoing; here the copper cell turns upon a pivot, as well as the zinc cylinder; and for an obvious reason they revolve in contrary directions.

## ELECTRO-DYNAMIC INDUCTION.

FARADAY was the first philosopher who discovered the laws of electro-dynamic induction. He showed that an electric current, or a magnet, is able by induction to develop at a distance electric currents in a conducting wire; in the same way as common electricity electrizes an insulated conductor by induction.

*Experiment 1.* To show the induction of a current by magnetism; take the coil, represented in *fig. 81.*, and place its extremities *c* and *z*, in connection with the respective binding screws of a galvanometer; suddenly insert a strong cylindrical magnet within the coil, and the needle will be instantly deflected, but it will almost immediately return to its original position; suddenly withdraw the magnet, and the needle will be deflected in the opposite direction.

Thus it appears that the induction of the current acts only at the instants of application and withdrawal of the magnet.

This explains the principle on which Clark's magneto-electric machine acts.

*Exp. 2.* Attach small copper cylinders near to the respective extremities of the wire *c* and *z*; and place a bundle of soft iron rods, (insulated from each other by a coating of shell-lac) into the coil; connect the wires *c* and *z*, with the poles of the battery; hold the copper cylinders in the hands, and suddenly withdraw one of the wires from the pole of the battery, and a pretty powerful electric shock will be felt, and at the same time a spark will be given off from the point of the wire; at the moment of restoring the contact another shock will be felt.

The current produced in these experiments is called a *primary current*: a *secondary current* is produced in the following manner.

Over the coil of wire described in the foregoing experiments, let an exactly similar coil be formed upon it; let *fig. 99.* represent this double coil, where *a* and *b* are the ends of the first or *primary* coil, *c* and *d* the ends of the second or *secondary* coil. Connect the ends *a* and *b* with the poles of a battery, and the ends *c* and *d* with a galvanometer; then the needle will be instantly deflected, showing that a secondary current had been induced in the second coil by the primary current in the first coil; suddenly take away one of the wires from the cup of the galvanometer and the needle will be deflected in the opposite direction. The induced currents only exist for an instant, viz., at the instant of making or of breaking the contact.

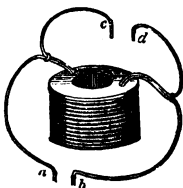


Fig. 99

#### MAGNETO-ELECTRIC MACHINES.

One of the most simple machines of this kind is represented in *fig. 100.* *J J*, is a sectional representation of a double induction spiral; *r r*, the wooden hollow roller on which the primary coil of stout copper wire, *a a*, is wrapped; *b b*, the secondary coil of fine wire surrounding the first coil; *m*, the bundle of iron wires placed in the hollow

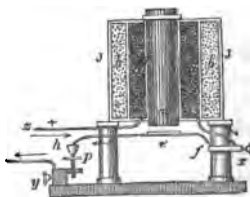



Fig. 100.

axis of the coils, and projecting with its lower pole a little beyond the wooden cylinder; one end  $z$ , of the wire of the primary coil, is connected with one pole of a constant battery, and the other end  $y h f x$ , of the wire of the primary coil, with the other pole of the battery; that portion of the conductor  $p h e f$ , between the two binding screws  $y$  and  $x$ , acts as the contact breaker. This *contact breaker* is constructed as follows: it is soldered at  $f$ , to a flexible plate screwed to the rod proceeding from the binding screw  $x$ ;  $e$ , is a plate of soft iron, soldered to the conducting wire, exactly under the electro-magnetic rods  $m$ ; at  $h$ , the conducting wire is bent downwards, and terminates with a hammer, having a platinum point, which rests upon a copper plate or anvil  $p$ . When the hammer  $h$ , is in contact with the anvil  $p$ , the electrical current is complete, and the soft iron wires  $m$ , become powerfully magnetised by the primary current, the magnet then attracts the plate  $e$ , and breaks the contact, the rods instantly lose their magnetism, and then the hammer  $h$ , falls upon the anvil  $m$ , and thereby again restores the electrical current; and so on. This process goes on with great rapidity, so long as the connection of the wires  $z$  and  $y$ , with the poles of the battery is maintained.

Vivid sparks are emitted between the hammer and the anvil, every time the connection is broken or made.

Substances to be subject to the action of the electric current, must be interposed between the binding screws  $x$  and  $y$ ; thus the thermal, chemical, magnetising, and physiological effects may be observed, at the instant the contact of the hammer with the anvil is broken or destroyed.

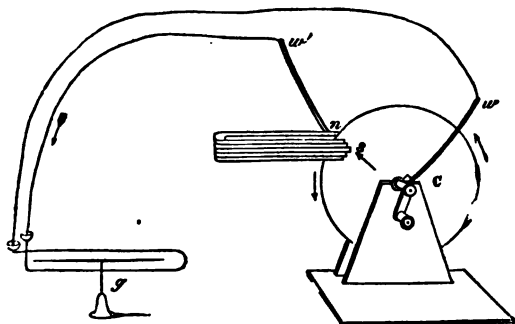


But the secondary current is that which should be used for producing the shocks or physiological effects. For this purpose the extremities of the wire forming the secondary coil *bb*, are soldered to small copper cylinders, and these are held in the hands of the person wishing to receive the shocks, one cylinder in each hand. A rapid succession of shocks is felt, for the effect takes place at every time the contact of the hammer with the anvil is broken or renewed.

This machine has been constructed in various forms; sometimes Richie's rotating magnet is used for breaking and renewing the connection of the conducting wire of the primary coil with the poles of the battery.

*Faraday's Magneto-electric Machine.*

The first machine of this kind was constructed by Faraday, as shown in *fig. 101*. It is thus described by Brand in his *Manual of Chemistry*.



*Fig. 101.*

*c*, is a copper plate, so mounted as to admit of  
K

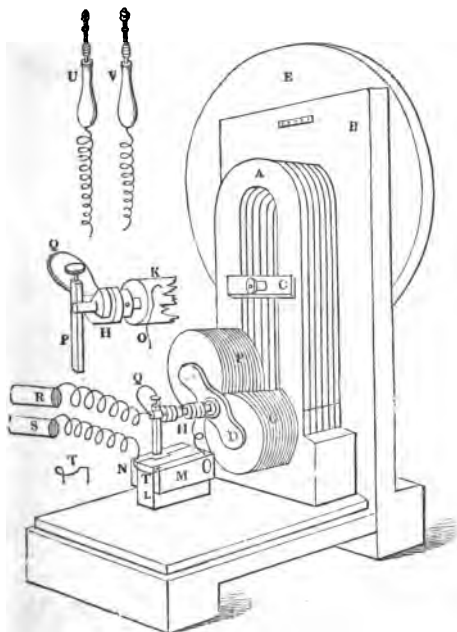
revolving on its axis;  $ns$  are the poles of a powerful horse-shoe magnet, so placed as to admit of the revolution of the plate between them;  $w w'$  are conducting wires, one of which is retained in metallic contact with the axis, and the other with the rim of the plate, at the point between the poles  $ns$ . These wires are connected with the galvanometer  $g$ . When the copper plate is made to revolve from right to left, a current of electricity is produced in the direction of the arrows, and deflects the galvanometer accordingly.

### *Clark's Magneto-electric Machine.*

Pixii first made a machine of this kind, which was successively improved by Saxton and Clark. The arrangement adopted by Clark is thus described by M. Becqu  rel in his treatise on Electricity.

A (*fig. 102.*) represents a series of six magnetized bars of steel, bent into a horse-shoe form, arranged vertically, and supported by four screws fixed to the board B, two of which are seen at  $mn$  (*fig. 103.*) A thick bar of brass C is pierced in its centre by an opening, into which passes a bolt with a nut for the purpose of securing the magnet against the board B. By this arrangement, the magnet may be easily removed without disturbing the rest of the apparatus. D represents the armature of a double cylinder of soft iron G F, which is fixed to a brass screw placed between the poles of the battery A. This piece is set in motion in the manner indicated in *fig. 103.*, by means of the wheel E, of an axis of rotation, and an endless cord. On each cylinder is rolled a helix of fine copper wire, coated with silk, and about 800 yards in length. One of the ends of each helix is soldered to the

armature; perpendicular to the surface of which, at D, is a brass rod supporting two break-pieces, H.

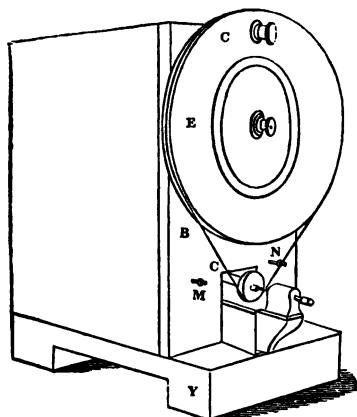


*Fig. 102.*

k represents a hollow brass cylinder, to which is soldered one of the free ends of the helices, and which is separated from the rod by means of a piece of hard wood resting on it; the other end of the helices is in communication with the rod. o is

2142<sup>k</sup>0

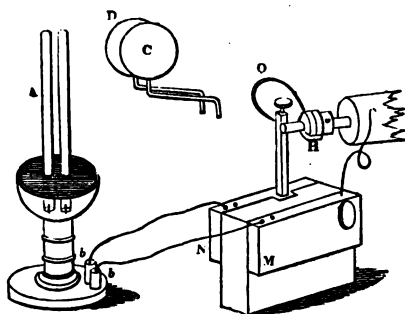
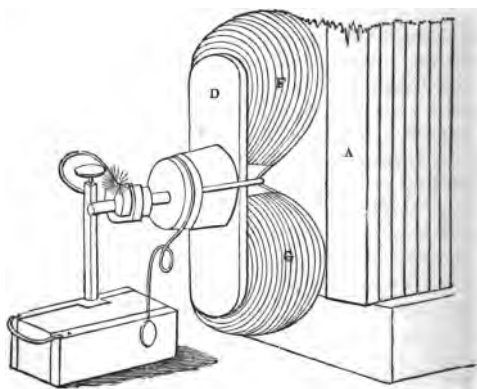
an iron wire spring to exercise a pressure against the hollow cylinder  $\kappa$ , with which it is in metallic contact, by means of a screw fixed in the brass plate  $M$ .  $P$  represents a square vertical brass rod fitted into the brass plate  $N$ .  $Q$  is a metal spring exercising a feeble pressure on the break-piece  $H$ :



*Fig. 103.*

it is held in metallic contact by means of a binding screw.  $T$  is a copper wire for making communication between the brass plates  $M$   $N$ . By means of this arrangement, these various parts  $D$ ,  $H$ ,  $Q$ ,  $P$ ,  $N$ , are in connection with one of the ends, and  $\kappa$  and  $M$  with the two other ends. It is very evident that, as the spring  $Q$  presses gently on the break-piece  $H$ , the effects are regular. . . . . It is very necessary that the break-piece be so arranged that

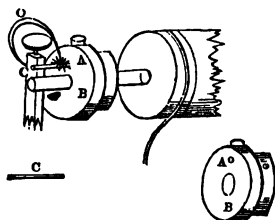
the spring *q* shall separate, at the very time when the iron cylinders of the armature are leaving the poles of the magnet. With respect to the iron wire *o*, it always exercises a gentle pressure against the hollow brass cylinder *k*. By means of these arrangements a mercury bath, which is always inconvenient, is superseded. When the shock is to be given by this machine, the two copper conductors *rs* (*fig.* 102.) are taken into the hands, which are moistened with salt water, one of the conductors being in communication with the plate *m*, and the other with the plate *n*, in the manner shown in the figure; *m* and *n* are then united by the piece *r*. The shock received by this apparatus as soon as the wheel is turned is very violent. If we desire a current always in the same direction, one break-piece only is placed on. In this case, the circuit is interrupted when the current changes, that is, when each helix quits one branch of the magnet. . . . On placing the two connecting wires *r s*, between *m n*, the shock is not so powerful.—*u* and *v* (*fig.* 102.) are handles connected with the conducting wires, and furnished with pieces of sponge, which are employed in the application of electricity for medical purposes. These sponges are moistened with acid or saline solutions. By means of them a succession of the most powerful shocks may be applied where they are needed. . . . To decompose water, Mr. Clark uses the apparatus (*fig.* 104.) arranged in the following manner:—*A* is an earthen vessel with a brass lid, having a base of hard wood, through which pass two copper wires soldered to platinum wires, and which are connected with *m n*. Two tubes *A*, are filled with water, and then placed over the platinum wires, where they are supported by a cork. The two

*Fig. 104.**Fig. 105.*

plates of platinum *c* and *d*, which are connected by copper wires with *m* and *n*, are for showing the effects of electro-chemical decompositions. For

this purpose, a piece of litmus or turmeric paper, previously moistened with a neutral salt, is placed between the discs. In the place of the two preceding helices and their accessories, which he calls the *intensity armature*, because the current obtained is from electricity of high tension, Mr. Clark employs a quantity armature formed of less powerful cylinders, and with a copper wire, covered with silk, only 45 yards long, the diameter of which is greater. *Fig. 105.* represents the apparatus furnished with this new armature. A is the horse-shoe magnet, D the armature, F and G the two helices. Attention must be paid that the spring quits the break-piece at the moment when the piece is vertical, for then it is that it is in a neutral position relative to the poles of the magnet. To fuse iron

wire with bright scintillations, one end of the wire is connected with the end P, and the other end is gently pressed on the rotating armature D. If we wish to obtain sparks of different colours by the employment of different metals, the break



*Fig. 106.*

piece is taken away, and the piece of copper B (*fig. 106.*) is substituted. In its open part, is introduced a piece of any metallic wire C, gold for example; the extremity of the spring G is also of gold. On making the apparatus rotate, purple coloured sparks are obtained."

## THERMO-ELECTRICITY.

THE electricity which is developed by heat is called thermo-electricity. When two different metal-rods, such as copper and platinum, or antimony and bismuth, are soldered together, and heated at the part of junction, electricity is generated.

*Experiment 1.* Twist the end of a copper wire round one end of a platinum wire; place the other extremities in connection with the binding-screws of a galvanometer; heat the twisted extremities with the flame of a spirit; the needle of the galvanometer will be instantly deflected.

*Exp. 2.* Fix two copper wires into the binding-screws of a galvanometer; heat the free end of one wire with the flame of a spirit-lamp; bring the free end of the other wire into contact with this heated wire; the needle will be instantly deflected, thereby showing the existence of an electric current. It is desirable that the end of the wire, which is to be heated, should terminate with a small plate.

*Exp. 3.* The simple apparatus, represented in *fig. 107.*, exhibits the effects of thermo-electricity in a very striking manner. *a b c d e* is a strip of copper, bent into the form shown in the figure, and rivetted at *e*. A small magnetic needle *n s* is suspended between the plates. Heat the free end *a* of the copper frame with the flame of a spirit-lamp, and the needle will be instantly deflected.



*Fig. 107.*

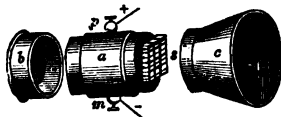
*Thermo-electric Batteries.*

These batteries are formed by soldering together a series of pairs of metal bars, as shown in *fig. 108.*, where the dark lines represent the bars of the same kind of metal, and the faint lines those of the other kind of metal. Heat is applied at the junctions, *a a a*, while the junctions, *b b b*, are kept cool.

*Fig. 108.*

The extreme ends *a b*, form the poles of the battery, which may be connected with binding-screws, &c. Bismuth and antimony are the two metals most commonly used in constructing these batteries, when the heat employed is moderate; but if the heat to which the battery is to be exposed is great, platinum and iron should be used.

A thermo-electric battery is sometimes used as a thermometer. *Fig. 109.* represents an apparatus of this kind. *a*, the tin or brass box which contains the thermo-battery *s*, composed of bismuth and antimony bars, arranged according to the principle explained in connection with *fig. 108.*; *m* and *p* the binding-screws connected

*Fig. 109.*

with the poles of the battery; wires pass from these binding-screws to the galvanometer; *b* and *c* are the two lids of the box. When heat, in any form, is applied at *s*, the deflection of the needle indicates

the degree of temperature of that heat. This instrument is much used for detecting *very minute* differences of temperature. A good instrument will readily detect, by the deflection of the needle, a difference of temperature of a hundredth part of a degree.

#### ACTION OF ELECTRO-MAGNETS UPON DIFFERENT BODIES.

All bodies which are capable of being magnetised are called *magnetic* bodies; but Faraday has recently shown that magnetism exerts on all bodies, more or less, a certain peculiar influence, very different from the magnetic; those bodies are called *dia-magnetic*. Thus the flame of a candle undergoes a peculiar change when placed between the poles of a powerful magnet; and light, when made to pass over the poles of a magnet, undergoes a change of polarity; and so on to various other dia-magnetic bodies.

THE END.

LONDON:  
A. and G. A. SPOTTISWOODE,  
New-street-Square.

# EXPERIMENTAL CHEMISTRY.

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## SECTION I.

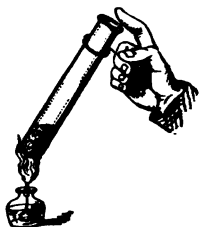
NATURE OF CHEMISTRY. SIMPLE AND COMPOUND  
BODIES. ATTRACTION. CHEMICAL AFFINITY.  
NATURE OF ACIDS AND ALKALIES. SOLUTIONS.

NATURE OF CHEMISTRY, SIMPLE AND COMPOUND  
BODIES.

**1. CHEMISTRY** is that science which treats of the properties of the simple substances composing the globe, and of the various compounds resulting from their action upon each other. So far as our present knowledge extends, there are sixty-two simple or elementary substances, which, uniting with each other, form the vast variety of substances found in the earth, the air, and the waters of the ocean and rivers. A simple substance, do with it what we may, will not yield any other kind of substance different from itself. Thus iron is considered to be a simple body, because we can only obtain iron from it. A compound body contains two or more simple substances in a state of chemical combination. Nearly all the substances in nature are of a

compound nature. Sulphur and iron are simple substances, but they combine and form a compound substance called sulphuret of iron.

*Experiment.* Take some iron filings and mix them intimately with about half their weight of sulphur; put the mixture into a test tube, and apply the flame of a spirit-lamp; at the same time close the mouth of the tube with the fore-finger, to exclude the air: the iron and sulphur combine with ignition, forming the compound of sulphuret of iron, a black substance entirely different from either the iron or sulphur.



2. Elementary substances are usually divided into two classes, namely, metallic and non-metallic. The following list comprises some of the most important elementary substances :—

#### *Non-metallic Elements.*

Oxygen, } gases found in the atmosphere ;  
 Nitrogen, }  
 Hydrogen, Chlorine, Carbon, Sulphur, Phosphorus, Iodine, &c.

#### *Metals.*

Potassium, the metal which forms potassa by combining with oxygen ;  
 Sodium, the metal which forms soda ;  
 Calcium, the metal which forms lime ;  
 Magnesium, the metal which forms magnesia  
 Iron, Copper, Zinc, Tin, Lead, Manganese,  
 Arsenic, Chromium, Mercury, Silver, Gold,  
 Platinum, &c.

3. There are many substances which, although they appear simple, are in reality of a compound nature. Thus water is a compound, being made up or composed of oxygen and hydrogen; the air is chiefly a mixture of oxygen and nitrogen; common salt is a compound, containing chlorine and sodium; and so on to other cases.

## DIFFERENT KINDS OF ATTRACTION.

4. *Attraction* is one of the distinguishing qualities of material substances. There are various kinds of attraction.

*Attraction of gravitation.* A stone falls to the ground in consequence of the earth's attraction, and the planets in the solar system are maintained in their orbits round the sun, by the attractive force which he exerts upon them. This is called the attraction of gravitation, and it subsists between bodies at all definite distances from each other.

5. *Magnetic attraction.* This is familiarly exhibited in the attraction which the poles of a magnet have for soft iron.

6. *Electrical attraction. Experiment.* If a stick of sealing-wax (or a glass tube) be rubbed sharply with a dry silk handkerchief, the sealing-wax will attract small cuttings of light paper: this is called electrical attraction.

7. *Attraction of cohesion. Exp. 1.* If an apple be cut in two, with a sharp knife, the pieces may be put together so as to adhere.

*Exp. 2.* Take two balls of lead; scrape a clean portion in each; bring the clean parts in contact, and rub the balls together by giving them a circular motion: they stick or cohere together.

*Exp. 3.* Two polished plates of metal placed

together require considerable force to separate them.

The force manifested in these experiments is called the attraction of cohesion or adhesion. The minute particles, or molecules, of which bodies are composed, are held together by the attraction of cohesion subsisting amongst these particles. Bodies are solid, liquid, or æriform, according as the force of cohesion is modified by heat.

8. *Capillary attraction* is a peculiar form of cohesion.

*Exp. 1.* Plunge the extremity of a small glass tube in water: the fluid rises within the small bore of the tube.

*Exp. 2.* Place a piece of lump sugar on a few drops of water: the fluid rises through the fine pores of the sugar.

[See page 27. of the Treatise on Hydrostatics.]

These facts are the result of capillary attraction.

#### CHEMICAL ATTRACTION, OR AFFINITY.

9. However intimately the sulphur and iron, in the experiment Art. 1. may be mixed, we can only by this means produce a mechanical mixture of the particles of the two substances; but, after chemical combination, there is no trace left of either the sulphur or the iron. Chemical affinity differs, in certain respects, from all other kinds of attraction. It resembles cohesion, inasmuch as it subsists between the particles of matter and holds them together; but while cohesion takes place between particles of the same sort, affinity is exerted between the particles of different kinds of matter; and while cohesion produces no change in the properties of a substance, affinity is almost invariably attended

with a marked change in the appearance and other properties of the substances forming the compound. All chemical changes are produced by affinity or chemical attraction. Combination and decomposition are the results of chemical action.

*Combination* takes place when particles of different kinds of matter unite and form a new substance.

*Decomposition* takes place when a substance is resolved into the different kinds of matter of which it is composed or made up.

### *Experiments.*

1. To a glass of water add a little oil: the oil floats upon the water, but does not combine with it. Water, therefore, has no affinity for oil.

2. Add ammonia; stir the mixture with a glass rod: the oil and the ammonia combine, and form a soapy substance, called a liniment. Oil and ammonia, therefore, have an affinity for each other. This is a case of simple combination.

3. To the soapy compound in the last experiment add a few drops of sulphuric acid (oil of vitriol); the ammonia, having a greater affinity for the sulphuric acid, quits the oil, and combines with the acid, forming the sulphate of ammonia: the oil, being set free, again floats upon the surface. This is a case of composition as well as of decomposition: it is therefore an instance of what is called *single elective affinity*.

4. Dissolve some acetate of lead (sugar of lead) in a glass of water\*; add a few drops of sulphuric acid: a white compound of sulphuric acid and

\* When any substance is dissolved in water, it is called a solution of that substance.

oxide of lead is precipitated, or falls to the bottom of the glass. This is also a case of single elective affinity.

5. To a solution of acetate of lead, add a few drops of a solution of sulphate of soda (Glauber salts): sulphate of lead is precipitated, as in the last experiment, and acetate of soda remains in solution. Here there is a mutual interchange of substances: hence it is called a case of *double elective affinity*.

10. Compositions, as well as decompositions, are continually going on in the processes of art and nature. A piece of chalk (carbonate of lime), heated to redness in the fire, gives off a substance called carbonic acid gas, and quick lime is left. When charcoal (the *carbon* obtained from wood) is burnt away, the oxygen in the air combines with the carbon or charcoal, and forms carbonic acid gas, which is, of course, thrown into the air, and is thus apparently lost; but there is no such thing as destruction or annihilation in nature, for substances can only change their form of combination. When a piece of lump sugar is dissolved in water, the sugar, although no longer visible, is not destroyed; it has combined with the water, forming a solution of sugar. In like manner, we are able to explain all other changes of form which bodies undergo around us.

## 11. NATURE OF ACIDS AND ALKALIES.

### *Experiments.*

1. Add a few drops of sulphuric acid to a glass of water; taste the diluted acid: it is sour or acid to the taste. Add a little of the *vegetable blue*

liquor of red cabbage\* to a glass of water ; add a little of the diluted sulphuric acid to this blue solution : it is changed to a red colour. The same experiment may be performed with any other acid.

*Thus acids are sour to the taste, and change vegetable blue colours to red.*

2. Ammonia, potassa, and soda are the most common and important alkalies. Add drop by drop of a solution of ammonia to the red liquor of the last experiment, until the red colour is changed to a greenish-blue. Taste the liquid : it is no longer sour or acid. Add now more acid, drop by drop, until the red colour is restored ; and so on.

*Thus alkalies neutralise the effect of acids, and change the vegetable blues to green.*

Blue slips of paper, stained by litmus†, are usually used to ascertain when an alkali exactly neutralises an acid.

3. To liquid ammonia add sulphuric acid, until a slip of blue litmus paper, dipped into the mixture, is about to change its colour to red. This is a solution of sulphate of ammonia. Here the sulphuric acid combines with the ammonia, and forms the sulphate of ammonia, the name of the compound being formed so as to indicate its composition. In like manner, carbonic acid united to lime forms the compound of carbonate of lime ; and so on to other cases.

In the same manner various other salts may be formed.

4. Take a small bit of phosphorus ; set fire to it upon a piece of glass or tin placed in the centre of

\* This is simply prepared by boiling common red cabbage, cut into small pieces, for a short time, in no more water than is just sufficient to cover them.

† Litmus is a vegetable blue.

a common plate, and immediately cover it with a large dry glass. The phosphorus, as it burns, combines with the oxygen of the air, and thus forms phosphoric acid, which rises in white flakes within the glass, and finally falls upon the plate like snow. These flakes have a



fine acid taste. After the ignition has ceased, pour a little water on the plate: this dissolves the flakes, and a solution of the acid is obtained.

This acid, combining with ammonia, forms phosphate of ammonia; with soda, it forms phosphate of soda; with lime, it forms phosphate of lime (which is principally the composition of bones); and so on.

5. Burn sulphur after the manner described in the last experiment. Here the sulphur, as it burns, combines with the oxygen in the air, and forms sulphurous acid, which rises, in the form of a colourless gas, into the interior of the glass. Put a violet flower (or a piece of litmus paper) into the glass: the colour is discharged. A little water poured into the plate dissolves the gas.

By a peculiar modification of this process sulphuric acid is made, which is a more powerful acid than sulphurous acid, in consequence of containing more oxygen.

#### SOLUTIONS.

12. When a substance dissolves in water, the substance is said to be soluble, and we obtain a solution of it. The solution of bodies in liquids

presents us with the most simple case of chemical attraction. Water readily combines with sugar, common salt, sulphuric acid, alcohol, &c.; and, on the contrary, it shows no tendency to unite with oil, ether, &c. Camphor readily dissolves in alcohol, but it is almost insoluble in water. The process of solution is much accelerated by heat and agitation. In order to obtain a concentrated solution of some substances, the liquid must be boiled in a common oil-flask for some time with the substance. Lime is sparingly soluble in water; yet, if a little lime be added to distilled water, a sufficient portion will be dissolved to indicate the presence of lime. Distilled or pure water should be used for making solutions; however, in most cases, clean rain water will do very well.

### *Experiments.*

1. Add a small piece of camphor to alcohol or spirits of wine; stir the mixture; the camphor is soon dissolved, and a clear solution of camphor in alcohol is obtained.

Pour a little of this solution into a glass of water; the alcohol unites with the water, and leaves the camphor floating upon the surface.

2. Add a little lime to a bottle of rain or distilled water; shake it up; and, after corking the bottle, set it aside until the particles of lime have settled to the bottom: pour some of the liquid into a glass, and a clear solution of lime is obtained.

3. Dissolve a little carbonate of potassa (pearlash) in a glass of water; a clear solution of the salt is thus obtained; add a few drops of this solution to lime water: it becomes milky, owing to the formation of carbonate of lime. Here the carbonic acid, having a greater affinity for lime than it has

for potassa, combines with the lime, and leaves the potassa in solution. The carbonate of lime is said to be precipitated; that is, it falls to the bottom of the glass, owing to its being nearly insoluble.

4. Breathe through a tube into a solution of lime: a milkiness is produced, owing to the formation of carbonate of lime. Here carbonic acid gas is expired from the lungs.

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## SECTION II.


FAMILIAR EXPERIMENTAL ILLUSTRATIONS OF THE PROPERTIES AND COMPOUNDS OF SOME OF THE MOST IMPORTANT SIMPLE SUBSTANCES.

### CARBON. CARBONIC ACID GAS.

13. WHEN wood is burned (as is done by the charcoal burners) in such a manner as to exclude the air, it is converted into wood *charcoal*, which is nearly pure *carbon*. The diamond is perfectly pure carbon in a crystallised form. Combined with other substances, carbon is found in vegetable, animal, and many mineral substances. When charcoal is burnt in the air it forms carbonic acid, a heavy gas, which extinguishes flame, and is destructive to animal life.

#### *Experiments.*

1. Put some pieces of chalk (carbonate of lime) into a bottle with a wide mouth; add sulphuric acid (or any other strong acid): violent effervescence



takes place, owing to the escape of carbonic acid gas with the formation of sulphate of lime. Here the sulphuric acid unites with the lime in the chalk, and the carbonic acid in it is set free in the form of gas.

2. In the last experiment the carbonic acid gas, as it is formed, gradually drives out the air in the bottle, and takes its place. This gas, being colourless, cannot be distinguished from common air by the eye: its presence, however, may be detected. Plunge a burning candle into the gas: the flame is instantly extinguished, while the gas remains unchanged.



Thus *carbonic acid gas extinguishes flame, and at the same time it does not take fire*, as some other gases do.

#### HYDROGEN. COMPOSITION OF WATER.

14. Hydrogen is a colourless, inflammable gas, and the lightest known substance in nature, it being about  $14\frac{1}{2}$  times lighter than air. Water is composed of hydrogen and oxygen. Hydrogen also enters into the composition of the inflammable or organic part of plants.

#### *Experiments.*

1. Put a few pieces of zinc cuttings into the wide-mouthed bottle (see last fig.); pour upon them some diluted sulphuric acid\*; the mixture soon effervesces, owing to the escape of bubbles of hydrogen gas, which gradually displace the air and fill the bottle. Cover the bottle with a plate, or with a

\* A mixture of 1 part of strong acid to about 4 or 5 parts of water.

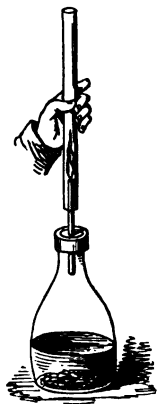
piece of window-glass \*, to prevent the external air from mingling with the hydrogen. When a sufficient quantity has been obtained, take off the cover, and plunge a lighted candle into the gas : the flame of the candle is extinguished, but the gas takes fire and burns at the mouth of the bottle, with a pale yellow flame.

When hydrogen is mixed with common air, the ignition goes on more rapidly, and sometimes with a slight explosion ; but the experiment may be made with perfect safety in the manner just described.

In this experiment, the sulphuric acid, the oxygen portion of the water, and the zinc, combine and form the sulphate of the oxide of zinc ; which remains in solution, while the hydrogen portion of the water escapes in the form of a gas.

Thus *hydrogen burns, but does not support flame.*

2. Generate hydrogen in a bottle, as in the last experiment ; and, *after the air has been driven out*, close the mouth with a cork, through which the tube of a tobacco-pipe passes ; light the gas as it issues from the fine opening of the tube. Insert this small flame a few inches into a glass tube, about 20 in. long and 1 in. in diameter. As the hydrogen burns, it combines with the oxygen of the air ; thus water is formed, which covers the interior of the tube in the form of moisture. After a short time, the tube emits musical sounds. These sounds are



\* N. B. In all experiments relative to gases generated in this way, it must always be understood that a plate, or a piece of window-glass, is to be laid over the mouth of the vessel for a few seconds, in order to exclude the external air.

produced by the air rushing in to fill up the void formed by the ignition of the hydrogen. To show the formation of water, a dry glass may be held over the flame.

#### OXYGEN AND NITROGEN. THE ATMOSPHERE.

**15.** The atmosphere is a mixture of oxygen and nitrogen: there is also a small portion of carbonic acid gas *always* present in the air.

#### *Experiments.*

1. Put a lighted wax candle on the table; place over it a glass jar, previously dried with care; the candle soon begins to burn dimly, as the inflammable substances in it consume the oxygen of the air, and, after a little time, the flame is extinguished; the interior of the glass will now be found covered with drops of water. Here the candle is extinguished, in consequence of the consumption of the oxygen, which, uniting with the hydrogen and carbon of the tallow, forms water and carbonic acid gas. See also Exp. 4., Art. 11.



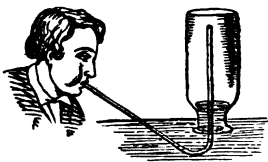
2. Put a lighted candle (supported by a bent wire passing through a cork) into a large bottle; close the mouth of the bottle: the flame soon becomes dim, and then goes out, in consequence of the air being no longer able to support combustion. Take out the candle, rekindle it, and plunge it into the bottle: the flame is immediately extinguished.



If a living animal were confined in a close bottle, after the oxygen in the air becomes vitiated, the

animal would die. A second animal, placed in this vitiated air, would at once expire.

3. Take a large bottle containing common air; place its mouth in water; close the nostril with the forefinger and thumb, and inspire and expire the air in the bottle, by means of a bent pewter tube, for a few seconds. At each inspiration the water rises in the bottle, and at each expiration the water

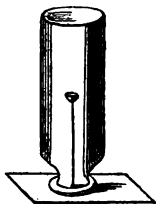


falls. Take the bottle containing the air which has thus been vitiated by passing through the lungs, plunge a lighted taper into it, as in Exp. 2.: the flame is extinguished. Here the oxygen of the air is consumed in the act of respiration, and the vitiated air returned to the bottle contains the nitrogen, which was at first in the air, mixed with carbonic acid gas. See also Exp. 4., Art. 12.

In the process of breathing, the oxygen taken from the air is returned to it in the form of carbonic acid gas; thus one great end of breathing consists in depriving the blood of its carbon or charcoal.

Thus *oxygen not only supports flame, but also animal life*: hence it is called vital air.

4. Place a wire, supporting a small cup, on a stand or shelf covered with water; put a small piece of phosphorus in the cup; ignite the phosphorus, and then invert a large bottle over it. The phosphorus consumes all the oxygen in the bottle, thereby forming phosphoric acid, and leaves the nitrogen. After shaking the water in



the bottle (its mouth being still kept under the water) the water rises, occupying the place of the oxygen which has been consumed. This will be found to be about  $\frac{1}{5}$  of the air at first in the bottle. The residue is nitrogen gas; thus showing that  $\frac{1}{5}$  of the bulk of the air is oxygen, and  $\frac{4}{5}$  are nitrogen.

5. Take the bottle of nitrogen (covering its mouth with a piece of glass) and place it on the table with its mouth uppermost; plunge a lighted candle into the gas: the flame is extinguished, at the same time the gas does not take fire.

*Thus nitrogen neither supports flame, nor does it take fire as hydrogen does.*

6. Put some green leaves beneath an inverted glass filled with water, and place it in the sunshine: the leaves will be found to give off oxygen gas.



*Thus plants give off oxygen gas, while animals consume it.*

7. Introduce some chlorate of potassa in powder (a salt which contains a large quantity of oxygen) into a test-tube; apply the flame of a spirit-lamp: the salt is decomposed by the heat, all the oxygen gas being given off; apply the finger lightly to the mouth of the tube, to keep the gas as pure as possible; plunge a lighted splinter of wood into the gas; the flame is much increased in brightness; before introduction, blow the flame out so as to have a red spark remaining: the wood



is instantly rekindled, thereby showing that pure oxygen is an eminent supporter of combustion.

8. Pour some lime water into a glass, and allow it to stand for a few hours : a skin of carbonate of lime is formed upon the surface. This shows that there is carbonic acid gas in the atmosphere.

#### AMMONIA.

16. This gaseous substance is composed of nitrogen and hydrogen. Water dissolves a large quantity of this gas, and the solution is called liquid ammonia or hartshorn. It readily combines with all the acids, and forms salts of ammonia. This substance is invariably given off from animal matter in a state of putrefaction ; the ammonia thus formed rises into the air, where it floats until it is washed down by the rains to fertilise the soil. It is one of the most fertilising substances found in farm-yard manure and guano.


#### *Experiments.*

1. Hold test paper over a bottle of liquid ammonia : a powerful alkaline action is exhibited. Smell the ammonia ; it has a strong pungent odour.

2. Dip a glass rod in hydrochloric acid, and hold it over a bottle of liquid ammonia : white fumes of hydrochlorate of ammonia are formed.

3. Take a bottle of hydrochloric acid into a horse stable ; take out the stopple of the bottle : white fumes, as in the last experiment, are formed about the mouth of the bottle.

4. Take two bottles ; put a little liquid ammonia into one of them, turning the bottle round so as to spread the ammonia over the interior ; in like manner introduce hydrochloric acid into



the other bottle; bring the mouths of the bottles together, as in the annexed cut: the dense white fumes of hydrochlorate of ammonia are produced.

5. Take equal parts of hydrochlorate of ammonia (sal-ammoniac) and quicklime, each separately powdered, and mix them briskly together; the strong pungent fumes of ammoniacal gas will be felt.



6. Perform the same experiment with a mixture of guano and quicklime: ammonia is in this case given off from the guano.

7. To a solution of carbonate of ammonia add a solution of oxalic acid until effervescence ceases: a solution of oxalate of ammonia is obtained. Here the acid and ammonia combine with the escape of carbonic acid gas.

#### NITRIC ACID, OR AQUA FORTIS.

17. This important substance is a compound of nitrogen and oxygen. It is manufactured from nitre (nitrate of potassa), a substance composed of nitric acid and potassa. There is reason to believe that nitric acid is formed in the air during thunder storms. Decaying organic substances containing nitrogen yield this acid. Nitric acid, as well as ammonia, supply the growing plant with nitrogen.

#### THE ATMOSPHERE.

18. THE ATMOSPHERE is that vast ocean of elastic fluid which everywhere surrounds the globe, extending to the height of about fifty miles above the tops of our highest mountains. This subtle elastic fluid bears on its tide the exhalations of the earth over every clime, descends to the lowest depths of our mines, and penetrates into the recesses of our

darkest caverns. Although invisible to the eye, and although bodies move through it with apparent ease, yet the chemist has weighed it in his balance, and determined its composition with an exactness which challenges dispute. Everywhere the composition of the air is the same\*,—as far as regards its essential elements,—whether it be taken from the confined alleys of our crowded cities, or from the mountain tops over which the healthful winds play with unobstructed freedom. Winds, air in motion, drive our vessels through the ocean, and perform useful labour in our windmills. The atmosphere is the great agent by which heat is nearly equally distributed over the earth, and without its agency light itself would scarcely serve the purposes for which it is designed. By its means moisture is scattered over the vegetable creation in the form of rain and dew; and these rains wash down ammonia, nitric acid, and various exhalations essential to the growth of plants.

The substances *essential* to the constitution of the atmosphere are oxygen, nitrogen, carbonic acid gas, and watery vapour. The oxygen, as we have shown, is necessary to the existence of the animal world, and to the support of combustion; while the nitrogen tends to moderate the intensity of the action of the oxygen. The comparatively small portion of carbonic acid gas in the air affords an important part of the food to the vegetable world, and the watery vapour, besides serving other important purposes, tends to keep the skin of animals and the surface of plants in a moist condition. The beautiful adjustment of the relative proportion of these substances to suit the wants of animals and

\* This arises from the diffusiveness of gases, or the tendency which they have to intermix with each other, without regard to their difference of density or heaviness.

plants, is a remarkable instance of the nice adaptation of means for the production of a proposed end.

The air is being continually supplied with carbonic acid gas from the respiration of animals; from the burning of wood, coal, and other combustible bodies; and from all animal and vegetable substances in a state of decay. Farm-yard manure, also, put into the soil in a fermenting state, yields an abundant supply of carbonic acid gas, as well as of ammonia, to the growing plant. The atmosphere, however, affords the chief source of carbonic acid to plants, which, assimilating the carbon, give off the oxygen into the air, to make up the deficiency produced by the respiration of animals. Guided by an unseen power, one part of creation administers to the necessities of another part: thus plants and animals are necessary to each other's existence,—the one supplies what the other consumes,—what is discharged as useless from the one becomes essential food to the other. This remarkable law of compensation seems to run through the whole of the universe, and a proper appreciation of its nature cannot fail in forcibly impressing upon our minds the great and solemn fact—that the universe is the work of a Being infinite in wisdom, goodness, and truth.

Thus the atmosphere, which appears as nothing to the vulgar eye, is not less essential to the economy of nature, than the solid matter of which the globe is composed, or the great ocean of waters which float upon its surface.

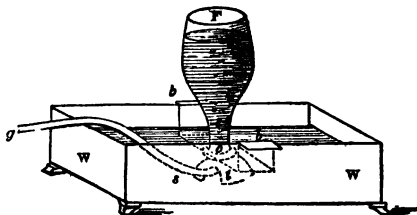
*Experiments, with Descriptions of Pneumatic Apparatus.*

1. Draw water into the mouth by a tube. Here the process of sucking draws the air from the tube,

and the pressure of the external air causes the water to rise in the tube. The pipette, used in many chemical experiments, depends on this principle. When the finger is placed upon the upper opening *c*, the fluid in the tube remains suspended; and, on the contrary, when the finger is removed, the fluid descends drop by drop from the small orifice *o* of the lower extremity. (For a complete account of the various mechanical properties of the atmosphere, see the Treatise on Pneumatics.)



2. Invert a bottle, *r*, filled with water, in the same fluid; the water remains suspended in the bottle by the pressure of the external air. Blow

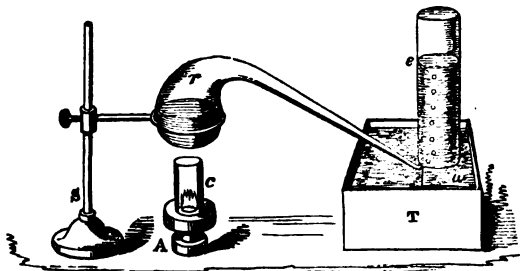


through a tube *g s t* into the mouth of the bottle; the air rises in bubbles through the water and displaces it.

This explains the principle upon which the *pneumatic trough* depends. This simple piece of chemical apparatus is used for receiving different kinds of gases in bottles and gas receivers: it consists of a rectangular trough, *w w*; with the shelf *b b*, having a funnel-shaped hole passing through it, for placing the bottles and receivers on; when it is about to be used, water is poured into the trough, so as to cover

the shelf to the depth of about an inch ; the mouth of the bottle intended to receive the gas is placed over the hole in the shelf, and the beak of the retort, in which the gas is being formed, is placed immediately below this orifice : the gas then rises in the bottle and displaces the water.

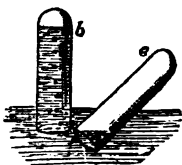
In the annexed cut, *r* is the retort, containing the mixture from which the gas is to be made, with its beak placed below the hole in the shelf *w* ; *t* the pneumatic trough filled with water ; *e* the gas re-



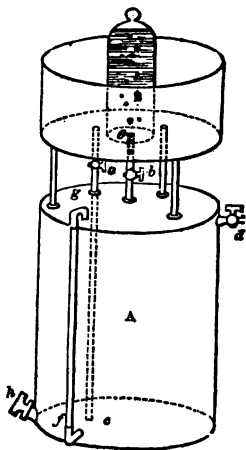
ceiver ; *s* the retort-stand with its ring supporting the retort *r* ; *A* an *Argand lamp* with its chimney *c*, for applying a steady heat to the retort when it is required for generating the gas : some gases, however, such as hydrogen, for example, are given off from the materials in the retort without the aid of external heat.

N. B. In the preparation of gases in this way, it should be observed that the gas which first comes over is mixed with the atmospheric air in the retort ; hence a volume of gas equal to about twice the volume of the retort should be thrown away as impure ; this should especially be attended to in the case of gases (such as hydrogen) which detonate when mixed with atmospheric air.

Gases may be transferred from one vessel to another over the pneumatic trough. In order to transfer the gas from *e* to *b*, bring the lower edge of *e* to the mouth of *b*; gradually depress the upper end of *e*; bubbles of gas will pass from *e* and fill the vessel *b*.



When a large quantity of gas is to be made, the *gas-holder* is preferable to the pneumatic trough. This valuable piece of apparatus consists of a closed cylindrical vessel *A*, and a shelf *B*, open at the top, supported on three rods; *a c* is a pipe, open at each extremity, reaching from the bottom of the shelf to the bottom of the cylinder; *e b* is another pipe which merely enters the top of the cylinder; communications can be opened by the cocks *a b*; *d* is a cock through which the gas in the cylinder may be drawn off; *h* is an aperture for introducing the pipe which conducts the gas into the receiver *A*; *f g* is a glass tube opening into the cylinder at the top and bottom, to show the quantity of gas that may be in the cylinder at any time. To fill the cylinder *A* with gas: *A* is first filled with water, which is done by opening the three cocks *a*, *b*, *d*, closing the aperture *h* with a cork, and pouring water into the shelf *B*: the water



runs through the pipes *a* and *b* into *A*, expelling the air through *d*. When *A* is filled with water the cocks *a*, *b*, and *d* are closed, and the aperture *h* is opened; the water remains in the cylinder *A* in consequence of the atmospheric pressure, just in the same way as water is suspended in the bird-fountain; introduce the tube proceeding from the retort into the aperture *h*; the gas will then rise in bubbles into the cylinder, displacing the water through *h*. To fill a jar *B* with the gas: pour water on the shelf *B*; open the cocks *b* and *a*; the gas then rises in bubbles into *B*, from the pressure produced by the column of water in the pipe *a* *c*. The gas may also be transferred through the cock *d*.

## SULPHUR.

19. This important elementary substance abounds, in its simple state, in the Island of Sicily, and in many volcanic countries. It is also found, in combination with iron and copper, in many parts of the world. Sulphuric acid is the most important compound of sulphur; united with various bases, such as lime, soda, magnesia, &c., it forms sulphates, which are found abundantly in the mineral kingdom.

*Experiments.*

1. Heat sulphur in a test-tube; the sulphur first melts, and then rises in vapour, which condenses in the cold part of the tube. See also Exp. 1., Art. 1.; and Exp. 5., Art. 11.

2. To a solution of baryta add sulphuric acid; the white precipitate of sulphate of baryta falls, which is not dissolved by nitric acid. This is the best test for the presence of sulphuric acid.

3. Put some sulphuret of iron in a bottle, and pour some diluted sulphuric acid upon it; sulphuretted hydrogen gas is given off, which has the

smell of rotten eggs; dip a slip of white paper in a solution of acetate of lead, and suspend the paper in the bottle containing the gas: the paper is rendered black from the formation of the sulphuret of lead.

*Sulphuretted hydrogen, or hydrosulphuric acid*, is highly inflammable, and is much used as a test for the presence of different kinds of metals. The fumes of this gas should be avoided, as it is deleterious to animal life.\*

#### PHOSPHORUS.

20. This elementary substance is very inflammable, and therefore should be handled with great caution. It has very much the appearance and consistence of wax. It is found in urine, and enters into the composition of animal bones.

#### *Experiments.*

1. Fold a thin slice of dried phosphorus in a piece of paper; rub it briskly with any smooth body: the heat produced by the friction speedily ignites the phosphorus.

2. Write upon the wall with a stick of phosphorus (wrapped round with a piece of paper); the writing appears luminous in the dark. See also Exp. 4., Art. 11.

3. *Phosphuretted hydrogen gas.* Put some zinc cuttings and a few small slices of phosphorus into a tumbler glass; take the glass into a dark room, and add some diluted sulphuric acid: the mixture appears like *a well of fire*, in consequence of the escape of phosphuretted hydrogen gas, which ignites spontaneously when it comes into the air.

\* All fumes given off by chemical action should be carefully avoided.

## IODINE.

**21.** This elementary substance is solid, having a dark bluish colour, with a somewhat metallic lustre. It is found in sea-water and marine plants. It is highly soluble in alcohol, but is sparingly dissolved in water. Its most important compound is iodide of potassium, which is now much used as a medicine.

*Experiments.*

1. Heat one or two grains of iodine in a flask: the beautiful violet vapour of iodine rises within the flask, and slowly condenses.

2. Dissolve a *very small* piece of iodine in water; the water has a brown colour. To this solution add a *cold* solution of starch\*: the beautiful blue compound of iodide of starch is formed.

3. Drop a small piece of iodine on a few grains of phosphorus: the substances combine with ignition.

4. To a *cold* solution of starch add a few drops of iodide of potassium; no action is produced: add now a little sulphuric acid to set the iodine free; the blue iodide of starch is formed.

## CHLORINE.

**22.** Chlorine is a greenish-yellow gas (hence its name) which has a pungent, suffocating odour; it is not inflammable, but it supports combustion; indeed, some bodies ignite in it spontaneously. It combines with the metals, forming chlorides; thus common salt is a chloride of sodium. With oxygen it forms acids; the most important of these is chloric acid, which, combined with potassa, forms chlorate of potassa, a salt largely employed in the manufacture of lucifer matches. Chlorine destroys all colouring matters and offensive effluvia.

\* Starch should be dissolved in hot water.

*Experiments.*

1. Put a table-spoonful of chloride of lime (common bleaching powder) into a bottle; add an equal bulk of hydrochloric acid; chlorine, in the form of a greenish-yellow gas, soon fills the bottle: introduce a lighted candle. it burns with a dull red-coloured flame in the gas; suspend a moistened slip of blue litmus paper (or any other coloured substance) in the gas: the paper is soon bleached by the gas.

2. To a mixture of common salt and black oxide of manganese, add sulphuric acid; chlorine gas is given off. This is a highly convenient way of using chlorine for purposes of fumigation. The chlorine destroys all noxious malaria.

3. Add hydrochloric acid so as to cover half a tea-spoonful of chlorate of potassa in powder, in a small bottle; chlorine gas (mixed with chlorous acid) is generated; dip a slip of writing-paper into oil of turpentine, and introduce it into the gas: combustion immediately takes place. Perform the bleaching experiment described in Exp. 1.

Chlorous acid explodes with great violence, when heated even to a moderate temperature.

4. Mix a few grains of powdered lump sugar with twice the quantity of chlorate of potassa; let fall a drop of sulphuric acid on the mixture: chlorous acid is disengaged, which immediately inflames the mixture.

5. Carefully fold in a piece of paper a little chlorate of potassa in powder, with a small piece of phosphorus; strike the mixture with a hammer; a loud explosion takes place.

6. *To inflame phosphorus under water.* Put some crystals of chlorate of potassa, together with a few slices of



phosphorus, into an ale-glass; fill the glass with cold water; let fall a few drops of sulphuric acid, by means of a pipette, on the chlorate of potassa: the acid takes up the potass from the salt, and sets free a compound of chlorine and oxygen, which inflames the phosphorus.

#### HYDROCHLORIC ACID.

**23.** Hydrochloric acid or muriatic acid is a gas, composed of hydrogen and chlorine; it is largely dissolved by water, forming common aqueous hydrochloric acid.

*Experiment.* Add diluted sulphuric acid to common salt, in a bottle; hydrochloric acid gas is given off with effervescence, and fills the bottle; suspend a slip of moist blue litmus paper in the gas; the colour is changed to red: plunge a lighted candle into the gas; the flame is extinguished.

In this experiment, the acid decomposes the salt, which is a compound of chlorine, sodium, and water; the hydrogen of the water unites with the chlorine and forms hydrochloric acid gas; and the oxygen of the water unites with the sodium and forms soda, which combines with the sulphuric acid and forms the sulphate of soda.

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### SECTION III.

#### METALS AND METALLIC OXIDES.

##### POTASSA AND SODA.

**24.** POTASSIUM and sodium, united with oxygen form potassa and soda. These important substances are called *fixed alkalies*, to distinguish them from

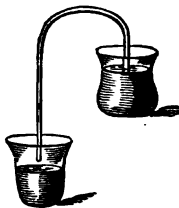
ammonia, which is called the volatile alkali. (See Art. 11.) Potassa is found in the ash of plants, and soda in the salt of sea-water.

### *Experiments.*

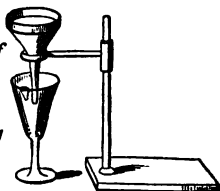
1. Throw a grain of potassium upon water; it floats on the water, and takes fire: a solution of potassa is formed, by the union of the oxygen of the water with the metal.

2. Burn some pieces of wood; collect the ashes, and pour water upon them to dissolve the potassa which is in them; add a solution of some vegetable blue: the colour is changed to green.

3. Boil, in an iron vessel, equal weights of slaked lime and carbonate of potassa (pearl ashes) in about twelve times the weight of water; the carbonic acid unites with the lime, forming the insoluble carbonate of lime, leaving the potassa in solution. Cover the mixture, and allow it to stand until the carbonate of lime subsides; draw the clear solution off by means of a syphon.\* When a solution of potassa is exposed to the air, it speedily takes up carbonic acid, and returns to the state of carbonate of potassa.



\* Insoluble substances, or precipitates, are usually separated from liquids by **FILTRATION**, *f* which consists in passing the liquid through *filtering paper* placed in a funnel *f*; by this process the clear liquid drops into the glass *g*, and the precipitate or insoluble substance remains on the filtering paper.



These filters are formed by making two folds, in a round



4. To a strong solution of carbonate of potassa, add a solution of tartaric acid; crystals of bitartrate of potassa (cream of tartar) are formed with the escape of carbonic acid gas.

5. Boil nitrate of potassa (nitre) in water, so long as any of the salt is taken up; decant the solution, and as it cools crystals of nitre, in six-sided prisms, are deposited.

*Soda* is found in the ashes of sea-ware; it is also obtained from common salt. The compounds of soda are very similar to those of potassa.

## LIME.

**25.** Chalk, limestone, marble, lime-shell and calcareous spar, are all compounds of lime and carbonic acid. Lime forms an essential constituent of all good soils. Mixed with vegetable or animal substances, it promotes their decay, and at the same time absorbs the noxious gases that are given off. Lime is an oxide of a metal called calcium.

*Experiments.*

1. Expose lime-water, in an open vessel, to the air; a crust of carbonate of lime soon appears upon the surface. See also Experiments 2, 3, and 4., Art. 12.

2. Pour hydrochloric acid upon some piece of piece of paper, at right angles to each other, and in a contrary direction; when this piece of paper is placed within the funnel, it will assume the form of *p*, shown in the cut. The liquid to be filtered should be carefully poured upon *the sides* of the filter, so as not to injure the paper at the bottom part. Before use, the filter paper should be moistened with distilled water.



chalk, so long as any effervescence is seen ; a solution of hydrochlorate of lime is formed.

3. Make a solution of nitrate of lime, by adding nitric acid to chalk, after the manner of the last experiment.

4. Pour a little of the solution of hydrochlorate of lime into an ale-glass, and about the same quantity of strong sulphuric acid into another glass ; pour the latter quickly upon the former ; a violent effervescence takes place from the escape of hydrochloric acid : a solid white substance, sulphate of lime is formed. Owing to the condensation, great heat is evolved.

5. To any solution of lime add oxalate of ammonia (see Exp. 7., Art. 16.) : the white insoluble oxalate of lime falls.

#### MAGNESIA.

26. This substance is found in sea-water, in certain varieties of limestone (magnesian limestone), and in many spring waters. Magnesia is the oxide of a metal called magnesium.

#### *Experiments.*

1. To diluted sulphuric acid add carbonate of magnesia (a white powder) until effervescence ceases : a solution of sulphate of magnesia (Epsom salts) is obtained.

Boil off or evaporate a portion of the water\* ; set aside the solution until it cools : crystals of the salt will be formed.

\* Evaporations are best conducted in porcelain dishes, or, as they are called, evaporating dishes ; the heat should be applied by a sand bath, or by an Argand lamp with a tin or copper chimney.

2. To a solution of sulphate of magnesia add a solution of carbonate of potassa : a white precipitate of carbonate of magnesia is formed.

This distinguishes Epsom salts from oxalic acid, a poison frequently mistaken for the former. It is further to be observed, that oxalic acid is sour to the taste, whereas Epsom salts are bitter. Oxalic acid is dissipated when thrown upon hot cinders, whereas Epsom salts leave a white mass behind.

#### ALUMINA.

27. This earth is an oxide of a metal called aluminium ; it abounds in common clay. It is distinguished by its insolubility, and by being dissolved in a solution of potassa. Alum is one of its most useful and common compounds. This salt contains alumina, potassa, and sulphuric acid. Pure clay is a compound of silica and alumina : in the proportion of about 3 parts of the former to 2 of the latter.

#### *Experiments.*

1. Add ammonia to a solution of alum ; alumina falls, in consequence of the ammonia combining with a portion of the acid.

2. Perform the same experiment, using potassa or soda.

3. In a saturated solution of alum, suspend a basket formed of woollen thread : the alum forms beautiful crystals on the thread, thereby forming an *alum-basket*.

#### SILICA.

28. This earth, like alumina, is very abundant in nature. Quartz is nearly pure silica, and it is the chief ingredient in sand and common flint. Mixed

with clay, it forms the great body of soils. Silica is an oxide of silicon.

### *Experiments.*

1. Mix one part of fine sand with three parts of carbonate of potassa; fuse the mixture in a crucible; carbonic acid is driven off, and the silica and potassa combine and form a glass, called silicated potassa, which readily dissolves in water; pour out the silicated potassa on an iron plate; dissolve a portion of it in water. This experiment is highly important, considered in relation to agricultural science.

2. To the solution of silicated potassa add a solution of hydrochlorate of ammonia; the hydrochloric acid combines with the potassa, and the silica is precipitated.

### IRON.

29. This valuable metal is found in a great variety of forms in nature. Combined with oxygen, it is found as an oxide of iron; with sulphur, as a sulphuret of iron; with carbonic acid, as a carbonate of iron.

### *Experiments.*

1. Place some iron-filings in a saucer; moisten them from day to day, until they become *rust*, or oxide of iron, by combining with oxygen.

2. To some iron-filings add diluted sulphuric acid: hydrogen gas is given off, and a solution of iron (green vitriol) is formed. Here the oxygen of the water combines with the iron, forming oxide of iron, which unites with the acid, forming the

sulphate of the oxide of iron, or, as it is simply called, sulphate of iron.

Decant the clear solution, evaporate it, and set it aside; when the solution is cold, green crystals will appear.

3. Add a few drops of a strong solution of sulphate of iron to 4 glasses containing water:—

- I. To the first add a solution of potassa; oxide of iron falls.
- II. To the second add a solution of carbonate of potassa: carbonate of iron falls.
- III. To the third add a solution of prussiate of potassa: a fine blue precipitate of Prussian blue is formed.

In these three experiments the sulphuric acid combines with the potassa, and remains in solution.

- IV. To the fourth add an infusion of galls: the black gallate of iron, the substance which gives the colour to ink, after a few seconds appears.

4. To a glass of water add a few drops of ink; add oxalic or hydrochloric acid: the colour disappears.

5. Write on paper with a very diluted solution of sulphate of iron; when dry, the writing is invisible; wash it over with a solution of prussiate of potassa: the writing appears of a fine blue colour.

#### COPPER.

30. This metal exists in nature in its pure or metallic state; but it is chiefly found as a sulphuret of copper (copper pyrites).

*Experiments.*

1. Heat copper for some time in the fire; suddenly plunge the heated copper into water: the oxide of copper is formed in scales on the surface of the metal.

2. Put some slips of copper into diluted nitric acid, which is colourless: a portion of the copper is soon dissolved by the nitric acid, and a fine blue solution of nitrate of copper is formed. Here a portion of the acid gives up oxygen to the metal, forming oxide of copper, which combines with the nitric acid. Red fumes of nitrous acid are given off.

By evaporation, this salt may be obtained in crystals.

3. Into a solution of sulphate of copper (blue vitriol) dip a clean piece of iron: the plate is covered with metallic copper. Here the copper is precipitated in consequence of the iron uniting with the acid to form sulphate of iron.

4. Add two drops of a strong solution of sulphate of copper to two glasses containing water: these solutions will be nearly colourless.

I. To the first, add a drop of ammonia; light-blue oxide of copper falls: add ammonia now in excess; the precipitate is redissolved, and the solution assumes a fine deep-blue colour. This is a very delicate test of the presence of copper.

II. To the second, add carbonate of potassa: light-blue carbonate of copper falls.

5. Place a few crystals of nitrate of copper on a piece of tinfoil; add a few drops of water to the crystals, and quickly fold up the tinfoil round them:

a violent chemical action takes place, and the tinfoil inflames.

## LEAD.

**31.** The most common native form of lead is sulphuret of lead, or galena.

*Experiments.*

1. Heat lead in an iron spoon : it soon melts, and then oxidates, by taking oxygen from the air.

2. Arrange seven glasses, each containing a diluted solution of acetate of lead (sugar of lead).

- I. To the first, add an alkali : the oxide of lead falls.
- II. To the second, add carbonate of potassa : the white carbonate of lead (white lead) falls.
- III. To the third, add sulphuric acid, or any sulphate : white sulphate of lead falls.
- IV. To the fourth, add hydrochloric acid : white chloride of lead falls.
- V. To the fifth, add a few drops of a solution of iodide of potassium : the beautiful yellow iodide of lead falls.
- VI. To the sixth, add a few drops of the solution of chromate of potassa : yellow chromate of lead falls.
- VII. To the seventh, add hydrosulphuret of ammonia : the black sulphuret of lead falls. See Exp. 4., Art. 60.

3. Suspend a piece of zinc in a moderately strong solution of acetate of lead : the lead appears deposited on the zinc in an arborescent form, producing what is called the *lead tree*. Here the zinc takes the place of the lead, and the latter is precipitated.

## CHROME.

**32.** The most common salt of this metal, is bichromate of potassa.

*Experiments.*

Arrange four glasses, each containing a diluted solution of bichromate of potassa.

1. To the first, add carbonate of potassa: it unites with the excess of acid, and yellow chromate of potassa appears.

2. To the second, add acetate of lead. See Exp. 2., Art. 31.

3. To the third, add a few drops of the nitrate of mercury: the orange-coloured chromate of mercury falls.

4. To the fourth, add a few drops of the nitrate of silver (lunar caustic): brick-red chromate of silver falls.

## MERCURY.

**33.** This metal is sometimes found native in the metallic form, but it is most commonly combined with sulphur. This metal is a fluid.

*Experiments.*

1. Heat a few grains of mercury in a test-tube over the spirit-lamp: the mercury rises in vapour, and condenses in globules in the cold part of the tube.

2. Heat a little sulphur, with about five times its weight of mercury, in a test-tube; close the mouth of the tube lightly with the forefinger: vermilion, or bisulphuret of mercury, is formed.

3. To a solution of chloride of mercury (corro-

sive sublimate) add a few drops of iodide of potassium : a red biniodide of mercury falls.

4. Heat some mercury with nitric acid ; the mercury takes oxygen from a portion of the acid, and combines with the other portion ; and a solution of nitrate of mercury is formed.

#### ZINC.

**34.** This metal is now much used for making water-pipes and spouts.

#### *Experiments.*

1. Take the solution of sulphate of zinc obtained by Exp. 1., Art. 14.; evaporate a portion of the water off ; set the liquid aside to cool : prismatic crystals of sulphate of zinc fall.

2. To a solution of sulphate of zinc add a few drops of ammonia (or potassa) : white oxide of zinc falls. Add ammonia in excess : the precipitate is completely re-dissolved.

3. To a solution of zinc add a few drops of the carbonate of ammonia : carbonate of zinc falls, which is re-dissolved by an excess of the precipitant. These two experiments form the tests\* for the presence of zinc.

#### SILVER.

**35.** Silver is distinguished by its brilliant lustre and fine white colour.

\* For a complete system of testing, the student may consult "Thomson's School Chemistry," or "Bowman's Chemistry."

*Experiments.*

1. To a few small pieces of silver add diluted nitric acid; apply heat until the acid ceases to give off fumes: a solution of nitrate of silver is obtained; as the solution cools, crystals are deposited.

2. To a solution of nitrate of silver add potassa: an ash-grey powder of oxide of silver falls.

3. To a very diluted solution of nitrate of silver add hydrochloric acid: chloride of silver falls in the form of a white, curdy substance, which soon becomes black upon exposure to the light.

4. Write upon linen with a solution of nitrate of silver; and, when the writing is dry, wash it with a solution of potassa: the writing soon becomes permanently black, owing to the formation of oxide of silver.

## GOLD.

36. This metal is not affected by exposure to the air, and ordinary acids produce no action upon it.

*Experiments.*

1. Put five or six gold leaves into a test tube; pour upon them a few drops of a mixture of nitric and hydrochloric acids; apply the flame of a spirit-lamp: the gold leaves are dissolved. Continue to apply a gentle heat, so as to expel any excess of acid: terchloride of gold remains. In this process, chlorine is set free from the hydrochloric acid, and combines with the gold.

2. Cover a slip of glass with a few drops of the terchloride of gold; apply the flame of a spirit-lamp: the chlorine is expelled, and gold is left upon the glass.

3. Put a drop of chloride of mercury on a gold ring; with the point of a penknife touch the gold through the drop: a permanently white spot of an amalgam of gold is produced.

## PLATINUM.

37. This metal is much used for making different kinds of chemical apparatus, on account of it being very infusible, and scarcely at all acted upon by ordinary chemical agents.

*Experiments.*

1. Mix nitric acid with an equal bulk of hydrochloric acid; add the mixture to a few small pieces of platinum wire in a Florence flask; digest, that is, keep the liquid at a slow boiling heat, until the acid is neutralised: a solution of bichloride of platinum is formed.

To obtain it perfectly free from acid, evaporate cautiously to dryness, and dissolve the residue in water.

2. Add a drop of the solution of bichloride of platinum to a glass of water; into this solution let fall a drop of iodide of potassium: a deep port-wine-coloured compound is immediately produced. The delicacy of this test is truly remarkable.

3. To the solution of bichloride of platinum, add a solution of hydrochlorate of ammonia: a yellow precipitate is formed, a compound of this salt and platinum.

Decant off the liquid and dry the precipitate; put it into the bowl of a tobacco-pipe, and bring it to a good red heat in the fire: metallic platinum, in a spongy state, is left, the other substances having been expelled by the heat.

4. Hold the spongy platinum before a stream of hydrogen gas: the metal soon becomes red hot, and the gas is ignited.

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## SECTION IV.

### DOCTRINE OF EQUIVALENTS. CHEMICAL NOMENCLATURE, SYMBOLS, ETC.

**38.** WHEN bodies combine with each other, it is always in certain fixed or definite proportions, that is, the same compound substance always contains the same elements combined in a constant proportion: thus water, whatever may be its quantity, or however generated, consists of 8 parts of oxygen to 1 part by weight of hydrogen: thus 1 part of hydrogen combines with 16 parts by weight of sulphur, to form sulphuretted hydrogen: thus 1 part of hydrogen combines with 6 parts by weight of carbon, to form carburetted hydrogen (olefiant gas). The numbers representing the proportional weights in which bodies combine, are called their *chemical equivalents*.

Taking 1 as the combining equivalent of hydrogen, 8 will be the combining equivalent of oxygen, 16 that of sulphur, and 6 that of carbon. Moreover, while 8 and 6 represent the proportional numbers in which oxygen and carbon respectively combine with hydrogen, these numbers also represent the proportion in which oxygen and carbon combine with each other or with any other substances: thus 8 parts of oxygen combine with 6 parts by weight of carbon, to form carbonic oxide. But this is not

all : when the same bodies combine in more than one proportion, the proportional numbers representing each successive compound are multiples (or it may be submultiples) of those in the first compound. This law is exhibited in the following examples :—

*Compounds of Carbon and Oxygen.*

	Proportion of Carbon.	Proportion of Oxygen.		
Carbonic oxide	- - - 6	+	8	= 14
Carbonic acid	- - - 6	+	16	= 22

*Compounds of Nitrogen and Oxygen.*

	Proportion of Nitrogen.	Proportion of Oxygen.		
Protoxide of nitrogen	- 14	+	8	= 22
Binoxide of nitrogen	- 14	+	16	= 30
Hyponitrous acid	- - 14	+	24	= 38
Nitrous acid	- - - 14	+	32	= 46
Nitric acid	- - - - 14	+	40	= 54

The equivalent of a compound body is the sum of the equivalents of its elements: thus the equivalent of carbonic oxide is 14, this number being the sum of 6 and 8; thus the equivalent of nitric acid is 54, this number being the sum of 14 and 40.

39. The following table contains a list of the names of the elementary substances, so far as they are at present known, with their symbols and combining equivalents. Those substances printed in italics are rare, and of comparatively little importance.

*Table of Equivalents and Symbols of Simple Substances.*

Sym.	Name.	Equiv.	Sym.	Name.	Equiv.
H	Hydrogen -	- 1	Mn	Manganese -	- 28
O	Oxygen -	- 8	Ni	Nickel -	- 30
N	Nitrogen -	- 14	Ba	Barium -	- 68
Cl	Chlorine -	- 36	Sr	Strontium -	- 44
C	Carbon -	- 6	As	Arsenic -	- 76
I	Iodine -	- 126	Sb	Antimony -	- 128
S	Sulphur -	- 16	Bi	Bismuth -	- 108
P	Phosphorus -	- 16	Te	Tellurium -	- 64
F	Fluorine -	- 18	V	Vanadium -	- 68
Br	Bromine -	- 78	U	Uranium -	- 60
B	Boron -	- 10	Mo	Molybdenum -	- 48
Se	Selenium -	- 40	Tn	Tungsten -	- 94
<i>Metals :</i>			Ti	Titanium -	- 24
K	Potassium -	- 40	Cm	Columbium -	- 184
Na	Sodium -	- 24	Nr	Niobium -	- ?
L	Lithium -	- 6	Pe	Pelopium -	- ?
Ca	Calcium -	- 20	No	Norium -	- ?
Mg	Magnesium -	- 12	G	Glucinum -	- 26
Si	Silicon -	- 8	Zr	Zirconium -	- 34
Al	Aluminum -	- 14	Th	Thorium -	- 60
Fe	Iron -	- 28	D	Didymium -	- ?
Cu	Copper -	- 32	Ln	Lanthanium -	- 48
Pb	Lead -	- 104	Ce	Cerium -	- 46
Zn	Zinc -	- 33	Y	Yttrium -	- 32
Cr	Chrome -	- 28	Tb	Terbium -	- ?
Hg	Mercury -	- 100	E	Erbium -	- ?
Ag	Silver -	- 108	Cd	Cadmium -	- 56
Au	Gold -	- 100	Pd	Palladium -	- 54
Pl	Platinum -	- 98	R	Rhodium -	- 52
Sn	Tin -	- 58	Os	Osmium -	- 100
Co	Cobalt -	- 30	Ir	Iridium -	- 98
			Ru	Ruthenium -	- 52

The arrangement of the elementary substances, in this Table, is merely adopted to suit the order observed in the other portions of this work.

**40.** The first letter or letters of the Latin name

of a simple substance, is taken as its symbol; and the symbol of any substance always represents its combining equivalent. Thus O stands for one equivalent of oxygen;  $2\text{O}$  or  $\text{O}_2$  stands for two equivalents of oxygen, and so on. Compounds are expressed by the equivalents of simple substances which enter into their composition: thus sulphuric acid is composed of one equivalent of sulphur and 3 equivalents of oxygen: the symbol of sulphuric acid, therefore, is  $\text{S} + \text{O}_3$ , or more simply  $\text{SO}_3$ , and the combining equivalent  $= 16 + 3 \times 8 = 40$ .

The sign of equality ( $=$ ) is used to express an identity of *composition*, but not always an identity in the *form* of the arrangement of the elements.

The names given to compound substances are such as to indicate their elementary composition.

Compounds containing oxygen are called *acids* or *oxides*, according as they do or do not possess acidity. Thus an oxide of iron contains oxygen and iron. The termination *ic* is placed to the name of a substance, when it becomes an acid: thus we have sulphuric acid, which is a compound of sulphur and oxygen. When the substance forms two acids, that which contains the smallest portion of oxygen terminates in *ous*; thus we have sulphurous acid. The termination *uret* also indicates the combination of a variety of substances: thus we have sulphuret of iron, which expresses a compound of sulphur and iron. Degrees of oxidation are sometimes expressed by Greek or Latin prefixes: thus *protoxide* expresses the first degree of oxidation, *binoxide* the second, *teroxide* the third, and so on. The highest degree of oxidation is usually expressed *peroxide*. When an acid, whose name ends with an *ic*, forms a salt, its name terminates with an *ate*: thus nitric acid forms a nitrate; while a sulphurous acid forms a sulphite, and so on to other cases.

*Exercises on the Use of Chemical Formulæ.*

**41.** One of the greatest advantages of chemical formulæ is, that they enable us to represent chemical combinations and changes with such clearness and precision.

$$\begin{aligned} 1. \text{ 1 eq. * water} &= 1 \text{ eq. hydrogen} + 1 \text{ eq. oxygen} \\ &= \text{H} + \text{O}, \text{ or } \text{HO}, \\ &= 1 + 8 = 9. \end{aligned}$$

$$\begin{aligned} 2. \text{ 1 eq. carbonic acid} &= 1 \text{ eq. carbon} + 2 \text{ eq. oxygen} \\ &= \text{C} + \text{O}_2, \text{ or } \text{CO}_2, \\ &= 6 + 2 \times 8 = 22. \end{aligned}$$

$$\begin{aligned} 3. \text{ 1 eq. nitric acid} &= 1 \text{ eq. nitrogen} + 5 \text{ eq. oxygen} \\ &= \text{N} + \text{O}_5, \text{ or } \text{NO}_5, \\ &= 14 + 5 \times 8 = 54. \end{aligned}$$

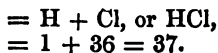
$$\begin{aligned} 4. \text{ 1 eq. potassa} &= 1 \text{ eq. potassium} + 1 \text{ eq. oxygen} \\ &= \text{K} + \text{O}, \text{ or } \text{KO}, \\ &= 40 + 8 = 48. \end{aligned}$$

$$\begin{aligned} 5. \text{ 1 eq. carbonate of potassa} &= 1 \text{ eq. potassa} + 1 \text{ eq. carbonic acid} \\ &= \text{KO} + \text{CO}_2, \text{ or} \\ &\quad \text{KO CO}_2, \\ &= 48 + 22 = 70. \end{aligned}$$

$$\begin{aligned} 6. \text{ 1 eq. ammonia} &= 1 \text{ eq. nitrogen} + 3 \text{ eq. hydrogen} \\ &= \text{N} + \text{H}_3, \text{ or } \text{NH}_3, \\ &= 14 + 3 \times 1 = 17. \end{aligned}$$

\* Eq. is used as an abbreviation of the word *equivalent*.

7. 1 eq. hydrochloric acid = 1 eq. hydrogen + 1 eq. chlorine



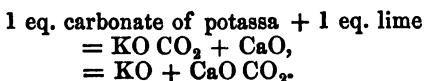
8. 1 eq. hydrochlorate of ammonia =  $\text{NH}_3 + \text{HCl}$   
 $= 17 + 37 = 54.$

9. 1 eq. bichloride of platinum =  $\text{Pt} + 2\text{Cl}$ , or  $\text{PtCl}_2$   
 $= 98 + 2 \times 36 = 170.$

10. 1 eq. lime = 1 eq. calcium + 1 eq. oxygen  
 $= \text{Ca} + \text{O}$ , or  $\text{CaO}$ ,  
 $= 20 + 8 = 28.$

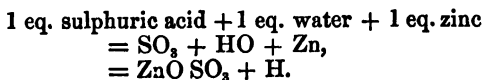
11. 1 eq. carbonate of lime =  $\text{CaO} + \text{CO}_2$ , or  $\text{CaO CO}_2$   
 $= 28 + 22 = 50.$

12. The action in Exp. 3., Art. 12. is as follows:—



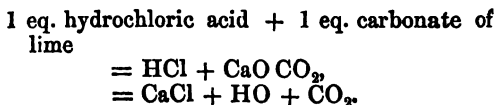
Here KO, or potassa, remains in solution, and  $\text{CaO CO}_2$ , or carbonate of lime, is precipitated.

13. The action in Exp. 1., Art. 14. is as follows:—



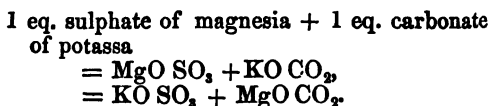
Here  $\text{ZnO SO}_3$ , or sulphate of oxide of zinc, remains in solution, and the hydrogen is given off.

14. The action in Exp. 1., Art. 13. is as follows :—



Here  $\text{CaCl} + \text{HO}$ , or chloride of calcium with water, is formed, and  $\text{CO}_2$ , or carbonic acid, is given off.

15. The action in Exp. 1., Art. 26. is as follows :—

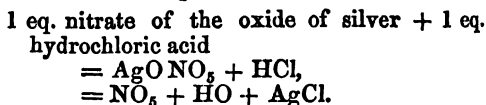


Here  $\text{MgO CO}_2$ , or carbonate of magnesia, falls, and  $\text{KO SO}_3$ , or sulphate of potassa, remains in solution.

16. 1 eq. nitrate of copper, or nitrate of the oxide of copper,



17. The action in Exp. 3., Art. 35. is as follows :—



Here  $\text{NO}_5$ , or nitric acid with water, remain in solution, and  $\text{AgCl}$ , or chloride of silver, falls.

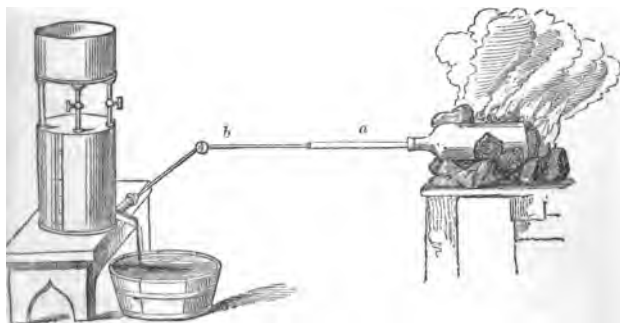
## SECTION V.

EXPERIMENTS CONDUCTED ON A LARGER SCALE, OR  
WITH A MORE COMPLETE APPARATUS.

## OXYGEN — O

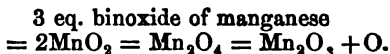
**42. Preparation.** To obtain oxygen pure, the substance which supplies it is placed in a retort or tube, and exposed to heat; when gas is evolved it must be collected over water, either in the pneumatic trough or in a gas-holder. See pages 20. and 21.

**43. Oxygen obtained from black oxide of manganese.** This substance is used by itself when large quantities of the gas are required. The oxide is introduced into an iron bottle, to the mouth of which an iron tube, *a*, is adapted, and luted or plastered over with common pipe-clay, made into paste with water. The extremity of this tube is luted to



a flexible tube, *b*, the outer end of which is inserted into the water of a gas-holder. The bottle is placed upon a good fire. When the manganese attains a red heat, it gives off a portion of its oxygen, which rises within the gas-holder.

The chemical changes which take place in this process are exhibited in the following formulæ: —



Here, after the process is completed,  $\text{Mn}_2\text{O}_3$ , or sesquioxide of manganese, remains in the retort. The gas should stand for a short time over water, in order to absorb any carbonic acid gas which it may contain.

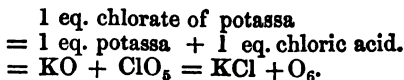
**44. Oxygen obtained from chlorate of potassa.** Mix about equal parts of chlorate of potassa and black oxide of manganese in a mortar; introduce the mixture into a small copper or green glass retort; apply the flame of a spirit-lamp, and receive the gas in the gas-holder, or the pneumatic trough.

If only a small quantity of the gas is wanted, the mixture may be intro-



duced into a large test tube, having a cork perforated by a bent exit tube, as in the annexed cut.

The decomposition is represented by the following formulæ: —



Here the heat resolves the chlorate of potassa

into KCl, or chloride of potassium, and  $O_6$ , or 6 eqs. of oxygen. The manganese in the mixture merely aids in keeping a steady heat.

### *Experiments with Oxygen.*

1. Introduce a lighted taper into a bottle of this gas: the flame is increased in size and brilliancy. Introduce a candle with a wick red: it bursts into flame.

2. Put some pounded charcoal on a cup attached to a wire passing through a cork; heat the charcoal, over a spirit-lamp, to redness; plunge it into the gas: the charcoal glows with great brightness, and bursts into flame. Here the product of combustion is carbonic acid gas.

3. Burn phosphorus in the same manner: it burns with great splendour.

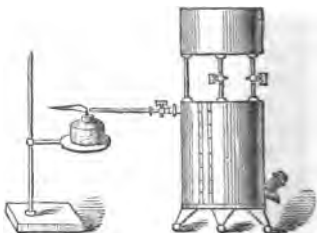
4. Burn sulphur in the same manner: it burns with a beautiful blue flame.

5. Roll a piece of fine steel wire in a spiral form round a glass tube: fix one extremity of the wire in a cork, and to the other extremity attach a piece of cotton wick dipped in melted sulphur; ignite the wick, and plunge it into a bottle of oxygen: the wire takes fire, and burns with beautiful scintillations. The product of combustion in this case is oxide of iron. To prevent the bottle from breaking, the bottom should be covered with sand



6. Introduce some dark-coloured venous blood into a bottle of oxygen: the blood, upon being shaken, soon acquires the florid colour of arterial blood.

7. Project the oxygen from a gas-holder on the flame of a spirit-lamp: great heat is produced. Hold a small piece of chalk or lime before the flame: the light of the lime is brilliantly white and intense. Burn a piece of watch-spring in the flame; &c.

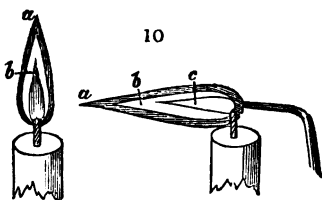


8. Take a large piece of charcoal, and make a small hole in it; hold this part of the charcoal over a lamp until it becomes red hot; drop a small cast-iron nail into the hole; hold the heated charcoal before a stream of oxygen (issuing from a jet with its orifice turned downwards): the charcoal burns rapidly; the nail becomes white hot, then fuses, and finally burns, giving off a brilliant shower of ignited sparks of the metal. This is one of the most beautiful experiments in the whole range of chemistry.

Various other metals may be ignited in the same manner.

*The common mouth blowpipe.* This consists of a brass tube, having a very small orifice or jet at one end, for projecting a small constant stream of air upon the flame. In the flame of a common candle, *b* is a hollow cone containing combustible gases in excess; this is surrounded by a sheet of flame *a*, where the combustible material is in contact with the oxygen of the air. When we blow through

this flame, by means of the blowpipe, the circumstances are completely changed; *b*, in the second figure, contains a powerful flame, having combustible gases



in excess; this portion is called the DEOXIDISING or REDUCING FLAME, for it deprives substances of their oxygen; *a*, in the second figure, is a flame where the oxygen preponderates; this portion is called the OXIDISING FLAME, for it communicates oxygen to the substance heated in it.

When a metal is to be brought to the state of an oxide, it is placed in the oxidising flame *a*; and when an oxide is to be *reduced* to the metallic state, it is placed in the deoxidising or reducing flame *b*. The most powerful heat is produced at the apex of the cone *c*.

In using the mouth blowpipe, the student must endeavour to acquire the power of keeping up a constant and steady blast, by forming his mouth into a bag of air, while at the same time he breathes through his nostrils. The manner of doing this is difficult to explain: by repeated trials, however, he will see that it is possible to do so.

*Experiment.* Place one or two grains of oxide of lead (litharge) on a piece of charcoal, and hold the substance in the reducing flame *b*; the metallic lead is produced in the form of a brilliant globule; bring the globule to the oxidising flame *a*; the metal is oxidised, and presents a dull appearance. Various other metals may be treated in the same manner.

The peculiar action of the flame of the blow-pipe constitutes a most interesting and useful department of experimental chemistry. On this subject the student may consult Griffin's "Chemical Recreations."

### HYDROGEN.

**45. Preparation.** This gas is most conveniently prepared from zinc and diluted sulphuric acid. Put some zinc cuttings, sulphuric acid, and about five times the quantity of water, into a retort *r* (see cut, page 21., Art. 18.) or into a bottle *b*, with the bent tube *t*; great heat is produced by the mixture of the acid and water, and the gas is copiously evolved, which may be received over water in the pneumatic trough or in the gas-holder. See Exercise 13., Art. 41.

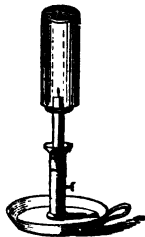


### *Experiments with Hydrogen.*

1. Invert a jar of hydrogen over a candle; the flame of the candle is extinguished, but the gas burns at the mouth of the vessel. In this way the gas takes some time before it is burnt away.

2. Ignite a jar or bottle of hydrogen, having the mouth of the vessel uppermost; in this case the gas burns much more quickly away, in consequence of its great lightness as compared with the air.

3. Introduce the gas into a jar *a*, having a gas-burner *g*, and stop-cock *c*; open the cock, and at the same time depress the jar in the



water; ignite the gas as it issues from the small orifice *g*; the gas burns with a pale yellow flame, which gives off a great deal of heat.

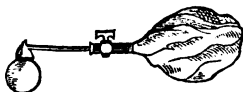
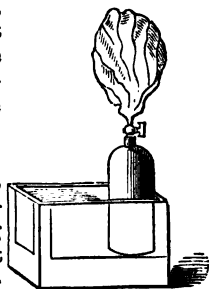
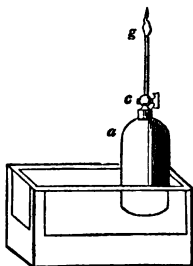
Hold a dry tumbler glass over the flame: water is deposited.

Repeat Exp. 2., Art. 14.

4. Mix in a strong bottle 1 measure of hydrogen with  $2\frac{1}{2}$  or 3 measures of common air; apply the flame of a candle to the mouth of the bottle: the mixture detonates with a considerable report.

5. Fill a bladder with this gas from a capped receiver at the pneumatic trough, as exhibited in the annexed cut, or from the gas-holder; adjust a common tobacco-pipe to the stop-cock, and blow soap bubbles by giving a gentle pressure to the bladder: these soap bubbles, being filled with hydrogen, are lighter than the air, and they ascend in the atmosphere like little balloons. Bring the flame of a candle in contact with one of these hydrogen bubbles: it explodes.

6. Fill a small balloon with hydrogen, or with common street gas, and load it with a light paper car, so as to keep it suspended in the air.



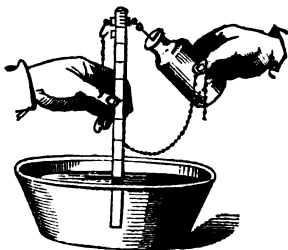
7. Throw a stream of hydrogen on spongy platinum. (See Exp. 3., Art. 37.) To ensure the success of the experiment, the platinum should be previously heated to redness before the spirit-lamp.

8. Mix over the pneumatic trough a portion of oxygen with twice its volume of hydrogen; fill a common soda-water bottle with the mixed gases; apply the flame of a taper: the gases detonate with a loud report.

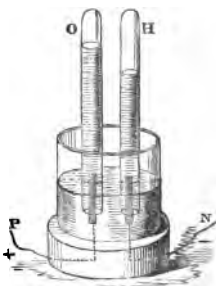
### *Composition of Water.*

46. It has already been explained that water is composed of 8 parts by weight of oxygen and 1 part of hydrogen. Now oxygen is exactly 16 times heavier than hydrogen; hence it follows that there must be double the quantity by volume of hydrogen to form water. The composition of water may be determined in two ways: first, by *synthesis*, or by bringing the elements together; second, by *analysis*, or by separating the elements from each other.

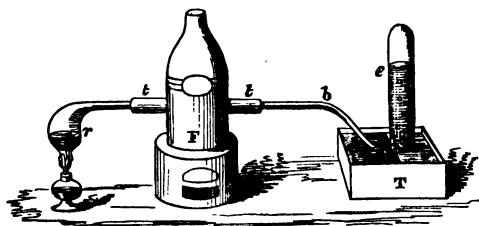
*Synthesis.* Introduce the mixed gases, 2 volumes or measures of hydrogen and 1 volume or measure of oxygen, into a strong graduated tube (Volta's *Eudiometer*), having two wires nearly meeting each other within the tube at the top; pass an electric spark through the mixed gases by means of a charged Leyden-jar, as shown in the annexed cut: the gases combine with ignition, water is formed, and a complete vacuum is produced, which is filled up by the ascent of the water in the trough.



*Analysis.* Two equal tubes, o and H, filled with water, are inverted over the two poles of a galvanic battery; when the battery is put in action the water is resolved into the two gases; the oxygen rises in the tube o placed over the positive pole, and the hydrogen into the tube H placed over the negative pole. As the analysis proceeds, it will be seen that the volume of the hydrogen is always double that of the oxygen.



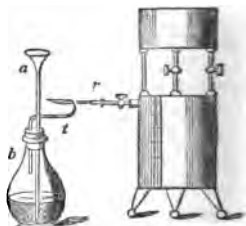
47. Water is also decomposed by passing a current of steam through an iron tube partially filled with iron-filings, and kept at a red heat by a furnace. In this cut, *r* represents the retort in



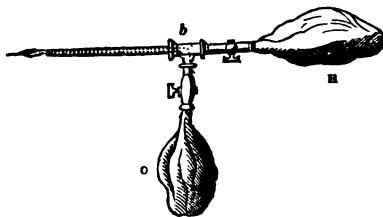
which the water is being boiled; *t t* the red-hot tube passing through the furnace *F*: the bent pipe *b* conveys the hydrogen gas into a jar *e* standing on the shelf of a pneumatic trough *T*. In this interesting experiment the steam passing over the heated iron is decomposed; the iron, taking up the oxygen, becomes an oxide of iron, and the hydrogen is disengaged.

*Ignition of the Mixed Gases.—Oxy-hydrogen Blowpipe.*

**43.** The simplest manner of showing the intense heat generated by the ignition of mixed gases is as follows. The hydrogen is formed in the bottle *b*, the cork of which is perforated by two tubes; *a* is a funnel-shaped tube, for the purpose of supplying sulphuric acid as it is required; *t* is a bent tube conveying the hydrogen for ignition\*; *r* is the tube with a stop-cock and jet, conveying a stream of oxygen from a gas-holder on the hydrogen flame. The various experiments described in Art. 44. may be tried with this flame.



**49.** *Daniel's blowpipe.* In this apparatus a

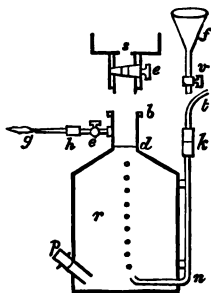


common tube *b* receives the two gases contained in the bladders *H* and *O*, provided with stop-cocks. the hydrogen is first ignited, and then the pressure upon the bladder containing the oxygen is regulated

\* This is an excellent arrangement for making hydrogen, as well as sulphuretted hydrogen, when large quantities are required.

so as to produce the maximum heating effect on the flame.

50. The following economical apparatus, answering the double purpose of a gas-holder and an oxy-hydrogen blowpipe, has been successfully used by the author of this work. In the annexed cut, *r* represents the gas receiver; *s* a shelf which screws on at *b*; *e* and *c* stop-cocks, as in the ordinary gas-holder (see p. 22.); *h g* a jet filled with wire gauze at the thick part *h*; *p* an aperture for receiving the beak of a retort; *n k* a bent pipe passing into the interior of the receiver *r*; *k t* a flexible tube, which screws on at *k*, and forms a connection with a bladder containing the mixed gases; *f* a funnel with a tube and stop-cock for screwing on at *k*. The tubular portion *d b* is about  $\frac{3}{4}$  inch internal diameter and 2 inches in length. When the apparatus is to be used as an oxy-hydrogen blow-



pipe, water is introduced into the receiver, so as to stand at the level *d*; the orifice at *b* is closed by means of a cork, and the bladder containing the mixed gases is screwed on at *k*; the safety jet *h g* is screwed on the stop-cock *e*; upon pressure being applied to the bladder, the mixed gases rise through the water, and filling the space *d b*, pass out in a strong stream through the jet *g*, and are there ignited. This arrangement is perfectly safe, for in the event of the flame passing along the safety tube *h*, we can only have an explosion of the gases contained in the small chamber *d b*, the only effect of which would be to blow out the cork in the orifice *b*, &c.

the large body of water in *r* most effectually cuts off all communication with the gases in the bladder. When the apparatus is to be used as a gas-holder, the shelf *s* is screwed on at *b*, the funnel *f* at *k*, and gases are received and transmitted in the same manner as in the ordinary gas-holder.

*Analysis of the Atmospheric Air by the Detonation of Hydrogen in Volta's Eudiometer.*

51. Mix over the pneumatic trough 2 volumes of atmospheric air and 1 volume of hydrogen; introduce a small portion of this mixture into the eudiometer tube (Art. 46.) so as to occupy 15 divisions of the tube; detonate by the electric spark: after detonation the gas only occupies 9 divisions of the tube; that is, 6 parts have disappeared, in consequence of all the oxygen having combined with a portion of the hydrogen to form water. Now the gaseous mixture in the tube contained 10 parts of air and 5 of hydrogen; and since water is composed of 1 volume of oxygen and 2 volumes of hydrogen, one-third of the diminution must give the quantity of oxygen in the 10 volumes of air originally in the tube; that is, 2 volumes of oxygen have disappeared; but 2 is one-fifth of 10; therefore one-fifth of atmospheric air is oxygen, and the remaining four-fifths are nitrogen: hence in 100 volumes of air, 20 are oxygen and 80 are nitrogen.

NITROGEN AND ITS COMPOUNDS WITH OXYGEN.

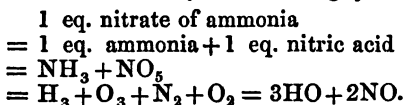
52. For the preparation and properties of nitrogen, see Art. 15., and Exps. 4. and 5.

*Protoxide of Nitrogen—NO.*

This gaseous compound is familiarly known by the name of the *laughing gas*, from the ludicrous effect which it has upon persons who respire it.

This gas is not inflammable, but it supports combustion with greater brilliancy than common air.

*Preparation.*—Introduce some crystals of nitrate of ammonia \* into a large retort; apply the heat of an Argand lamp having a copper flue, to give steadiness to the flame: at a temperature of  $400^{\circ}$  the salt fuses, and then gives off the gas in great abundance, which may be received in the gas-holder filled with *warm* water, as cold water largely absorbs the gas. It should stand for two or three hours over a little water, to absorb any fumes of nitrous acid that may be formed in the process. The whole of the salt is resolved by heat into this gas and water, as shown by the following symbols:—



Hence it appears that 1 eq. of nitrate of ammonia yields 3 eq. of water and 2 eq. of the protoxide of nitrogen.

### *Experiments.*

1. Plunge a burning candle into a bottle of this gas: the flame is much increased in brilliancy in consequence of the large quantity of oxygen which the gas contains.

2. Introduce a large splinter of wood having a glowing red spark into this gas: the flame is re-kindled, as in the case of oxygen gas.

3. Transfer this gas from the gas-holder into a

\* To prepare this salt, add carbonate of ammonia in powder to nitric acid diluted with about three parts of water until effervescence ceases; evaporate the solution until a drop of the liquid let fall upon a cold plate becomes a solid mass. A little ammonia should be added towards the close of the process to render the salt perfectly alkaline.

damp bladder having a wide wooden mouth-piece; place the mouth-piece between the teeth of the person who is to inhale the gas; let him close his nostrils with his forefinger and thumb, and then let him breathe the gas in the bladder: various effects, more or less ludicrous, are produced upon persons inhaling the gas. All kinds of apparatus should be removed, for they are liable to be injured by the inhaler.

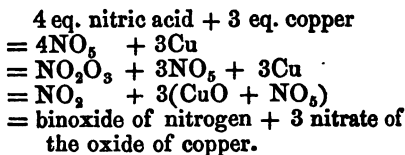


### *Binoxide of Nitrogen — NO<sub>2</sub>.*

This compound is a colourless gas, similar in appearance to common air: it is sparingly absorbed by water.

*Preparation.* — Put some copper cuttings into a retort, pour nitric acid upon them, and then add about an equal quantity of water\*: brisk effervescence takes place without the aid of heat, and the gas may be collected over water in the pneumatic trough.

The decomposition is represented by the following formulæ: —



### *Experiments.*

1. Transfer a bottle of this gas over the pneu-

\* The diluted acid should have a specific gravity of 12.

matic trough into a similar bottle nearly filled with common air; red fumes of nitrous acid ( $\text{NO}_2$ ) are instantly formed, which are soon absorbed by the water. This constitutes a characteristic property of the binoxide of nitrogen, and it is used in this way to detect the presence of free oxygen.

2. Plunge a piece of burning phosphorus into a bottle of this gas: the phosphorus continues to burn.

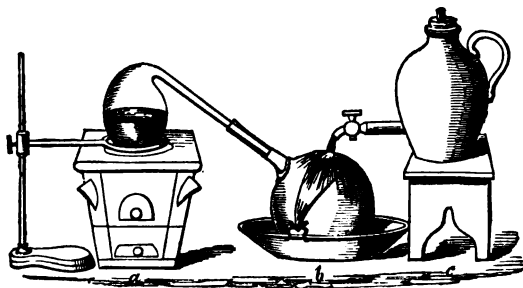
3. Burn a mixture of this gas and hydrogen (see cut to Exp. 3., Art. 45.): the mixed gases burn with a green-coloured flame.

4. Transfer a bottle of binoxide of nitrogen to a cup containing a solution of sulphate of iron: the solution becomes black.

### *Nitric Acid* — $\text{NO}_5$ .

For the leading properties of this acid, see Art. 17.

*Preparation.* Mix equal weights of nitrate of potassa (nitre) and oil of vitriol of commerce in a retort; heat the retort over a chauffer *a*, containing heated charcoal (a sand bath or an Argand lamp would answer the purpose equally as well): nitric

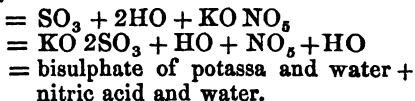


acid distils over, and is condensed in the liquid form

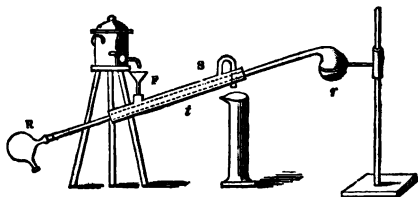
in the receiver *b*, kept cool by a stream of water proceeding from a jar *c*. The stream of water may be conveniently supplied from a funnel having its tube partially closed by a piece of rag.

The decomposition is as follows:—

2 eq. sulphuric acid + water + 1 eq. nitrate of potassa



**DISTILLATIONS** of any kind are conveniently effected by means of **LIEBIG'S CONDENSING TUBE**.



The liquid to be distilled is placed in the retort *r*, to which a sufficient heat is applied to boil the liquid: the vapour, as it passes along the tubes, is condensed by the cold kept up in the condensing tube *s t r*, and the liquid drops into the receiver *R*. The construction of this condensing tube is exceedingly ingenious: *t* is a wide tin tube; *f* a funnel passing into it for the purpose of supplying cold water; *s* a syphon for carrying off the hot water; a glass tube passing through this tin tube is connected with the beak of the retort and the receiver *R*; this glass tube passes through perforated corks inserted at each end of the tin tube *t*. Now this glass tube is continually surrounded by cold

**water**; for while cold water is being supplied by the funnel F, the water, as it becomes heated, rises within the tin tube, and is carried off by the siphons.

*Experiment.* Heat gently some oil of turpentine in a porcelain basin; pour suddenly upon it a mixture of 1 part of sulphuric acid and 2 parts of nitric acid: combustion takes place, with the evolution of a dense smoke. In order to avoid accident, the mixed acid should be poured from a bottle tied to the end of a stick.

**CARBON, SULPHUR, AND PHOSPHORUS, THEIR COMPOUNDS WITH OXYGEN AND HYDROGEN.**

### *Carbonic Oxide — CO.*

**53.** This is a colourless gas; it is the gas that burns with a blue flame at the top of a coke or charcoal fire.

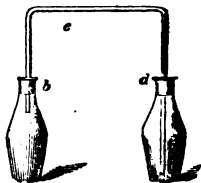
*Preparation.* Mix pounded oxalic acid with sulphuric acid in a retort, and apply heat: carbonic oxide and carbonic acid gases are given off, which may be received over the pneumatic trough. By allowing the gases to stand over water for a few hours, or by agitating them with lime water, the carbonic acid gas is absorbed, and the carbonic oxide is left pure. Oxalic acid may be regarded as a compound of carbonic oxide and carbonic acid with water; thus:—

1 eq. oxalic acid =  $C_2O_3$  + water = CO +  $CO_2$  + water. Now, the sulphuric acid combines with the water and sets the two gases free.

*Experiment.* Plunge a lighted taper into a bottle of this gas: the taper is extinguished, but the gas burns at the mouth of the bottle with a beautiful blue flame: thus *carbonic oxide is inflammable, but it does not support combustion.*

*Carbonic Acid* —  $\text{CO}_2$ .

**54. Preparation.** Carbonic acid gas, being more than  $1\frac{1}{2}$  times heavier than common air, may be prepared sufficiently pure by the following process. The gas is generated in the bottle *b* (see Exp. 1., Art. 13.); a bent tube *bed* passes through a cork *b*, and descends to the bottom of the open bottle *d*: as the gas enters the bottle *d*, the common air is displaced.\* A little experience will readily enable the experimenter to ascertain when the bottle is filled with the gas.



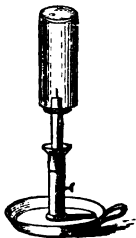
When this gas is received over the pneumatic trough, the water should be warm; for carbonic acid gas is largely absorbed by cold water.

*Experiments.*

1. Invert a jar or bottle of the gas over a burning candle: the gas by its gravity, falls upon the candle, and extinguishes the flame.

2. Place a burning candle in an open jar; take a bottle of carbonic acid gas, and pour it into the jar: the flame is extinguished. This shows that carbonic acid gas is much heavier than common air.

3. Pour some lime-water into a bottle containing this gas: carbonate of lime is formed: shake the liquid, and it becomes clear, in consequence of the carbonate of



\* Gases which are lighter than the air, such as ammoniacal gas, may be received in bottles with their mouths inverted.

lime being soluble in an excess of carbonic acid. In this way lime is dissolved in spring-water.

4. Add a little water to a bottle of the gas; shake the bottle: the water takes up the gas, and requires decided acid properties; add a little solution of litmus: the blue is changed to red.

*Carburetted Hydrogen—CH<sub>4</sub>.*

55. This gas is formed in marshes and stagnant pools; it is but little more than half the weight of common air; it is highly inflammable, and forms the *fire-damp* of the miners. When coal is heated to redness, it is resolved into tarry matter, and certain gaseous compounds of carbon and hydrogen, containing about 70 per cent. of carburetted hydrogen.

*Experiments.*

1. Invert a bottle filled with water in a stagnant pool; insert a funnel into the bottle to catch the gas; stir up the bottom of the pool with a stick: bubbles of carburetted hydrogen gas rise, which are easily received through the funnel. Ignite the gas thus obtained: it burns with a yellow flame.

2. Mix 1 measure of this gas with 7 or 8 of common air, in a bottle; apply the flame of a candle: the gas explodes with some violence. Mix 1 measure of the gas with 3 or 4 measures of air, and ignite the gases: they burn without explosion.

3. Put some pounded coal into a test-tube, fitted with a cork and the stem of a tobacco-pipe; apply the flame of a spirit-lamp: gas is disengaged, which may be inflamed as it issues from the small orifice of the pipe.

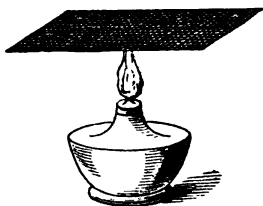
4. The flame of a candle is produced by the ignition of carburetted hydrogen gases. Bring

one extremity of a tube, about  $\frac{3}{8}$ ths of an inch in diameter, into the centre of the flame of a candle: the gases rise up the tube, and may be ignited as they escape at the upper end. This experiment also shows that flame is hollow.

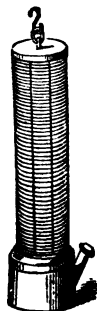


**56. The Davy lamp.** Carburated hydrogen occurs in coal-pits from the decomposition of the coal, where it sometimes explodes by coming in contact with flame; and thus melancholy accidents take place. The Davy lamp is designed to prevent these explosions.

*Experiment.* Take a piece of fine wire gauze: hold it across the flame of a lamp; the flame does not pass through the gauze. Blow out the flame, and ignite the smoke as it rises through the gauze: the flame does not descend below the gauze.



This experiment exhibits the principle upon which the Davy lamp is constructed: the metal, being a high conductor of heat, cools down the temperature of the inflammable matter in contact with it, and thereby extinguishes the flame on the side opposite to the burning body. The Davy lamp simply consists of a lamp surrounded by wire gauze to prevent flame extending from the interior of the lamp to the adjacent atmosphere.



*Olefiant Gas, or Heavy Carburetted  
Hydrogen—C<sub>4</sub>H<sub>4</sub>.*

**57.** This gas, owing to its illuminating power, is the most valuable constituent of street gas. It contains a larger quantity of carbon than the light carburetted hydrogen. Coal gas, when well prepared, contains about 20 per cent. of olefiant gas.

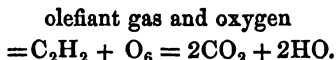
*Preparation.* Mix 1 part of alcohol with 5 or 6 parts of sulphuric acid in a retort; apply the heat of an Argand lamp: the gas comes over in great abundance, which may be received, over water in the pneumatic trough.

*Experiments.*

1. Plunge a lighted candle into a bottle of this gas: the flame of the candle is extinguished; but the gas burns, at the mouth of the bottle, with a fine, brilliant flame.

2. Burn this gas in a capped receiver. (See cut to Exp. 3., Art. 45.)

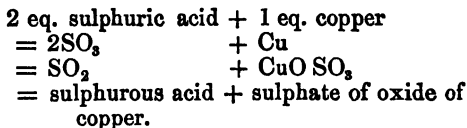
3. Mix 3 volumes of oxygen with 1 volume of olefiant gas in a strong common soda-water bottle; ignite the mixed gases: a violent explosion takes place, carbonic acid and water being formed: thus we have



1. Mix 2 measures of chlorine with 1 measure of olefiant gas in a bottle; introduce a lighted candle: the gases burn with a red flame, with a copious deposition of lamp black, thereby showing that olefiant gas contains carbon.

*Sulphurous Acid* —  $\text{SO}_2$ .

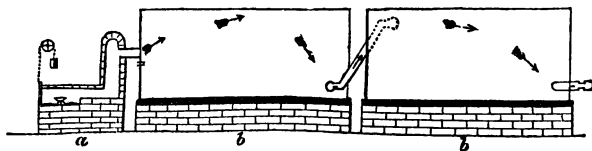
**58.** This acid may be procured in a pure state by boiling in a retort sulphuric acid with copper cuttings : the gas may be received by displacement, as in Art. 54. The action is represented by the following symbols : —



By passing a current of the gas through water, a solution of sulphurous acid is obtained. It unites with bases, forming sulphites. The gas is used in bleaching woollens.

*Sulphuric Acid* —  $\text{SO}_3$ .

**59.** This valuable acid is made by the manufacturer on a large scale, by burning sulphur in a furnace, where nitric acid is, at the same time, formed by the decomposition of nitrate of soda by means of sulphuric acid : the sulphurous and nitric acids pass into a succession of leaden chambers containing a portion of water, to dissolve the sulphuric acid as it is being formed by the nitric acid giving up a portion of its oxygen. In the annexed cut a

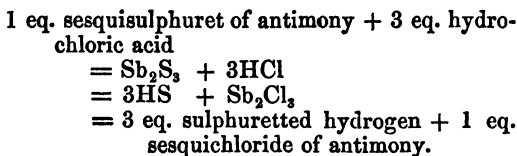


represents the furnace in which the sulphurous and nitric acids are formed; *bb* the leaden chambers containing some water. The sulphur is spread over the bottom of the furnace, and the nitre is placed in the cup, shown in the cut. The second chamber communicates with a high chimney, for creating a draught, and also for carrying off the surplus vapours.

*Sulphuretted Hydrogen, or Hydrosulphuric  
Acid — HS.*

**60. Preparation.** Heat sulphuret of antimony in a retort, with 4 or 5 times its weight of hydrochloric acid, and collect the gas over warm water in the pneumatic trough (or by displacement, as in Art. 54.). As the bottles are filled with the gas, they should be speedily removed and closed.

The action is represented in the following symbols:—



*Experiments.*

1. Invert a jar of this gas; apply a lighted match: the gas burns with a pale blue flame with the deposition of sulphur.

2. Pour a few drops of strong nitric acid into a bottle of this gas, and immediately close the mouth with the thumb protected by a piece of paper: an explosion takes place with the deposition of sulphur.

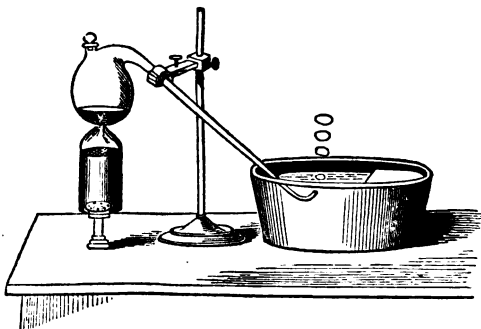
3. Generate the gas in a flask fitted with a cork and bent tube passing into a solution of arsenious acid (arsenic of commerce): an orange-coloured precipitate is formed of a sulphuret of arsenic. Sulphuretted hydrogen is much used in this way as a test for metals.



4. Transmit, as in the last experiment, a current of the gas through liquid ammonia: a solution of hydrosulphuret of ammonia is formed. This solution is much used as a re-agent.

### *Phosphuretted Hydrogen — $\text{PH}_3$ .*

61. *Experiment 1.* Put some thin slices of phosphorus into a small retort, and fill it completely with a mixture of *lime* and warm water; insert the beak of the retort in a vessel containing warm water; boil the mixture: bubbles of phosphuretted hydrogen gas are given off, which, escaping

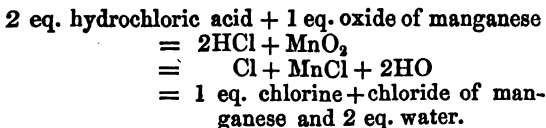


into the air, ignite spontaneously, and form beautiful rings of smoke.

2. Invert a test-tube filled with water over the beak of the retort in which the gas is being formed : the tube is soon filled with the gas. Observe that the gas is colourless and transparent like common air ; cover the mouth of the tube with the forefinger, and transfer the gas into a jar of oxygen standing on the shelf of the pneumatic trough ; the bubbles as they rise into the jar catch fire, giving a splendid flash of light.

### CHLORINE — Cl.

**62. Preparation.** Introduce into a retort hydrochloric acid and black oxide of manganese, so as to form a thin paste ; heat the mixture with an Argand lamp : chlorine gas is speedily given off, which may be recognised by its peculiar colour and suffocating odour ; receive the gas over warm water in a small pneumatic trough (or by displacement, see Art. 54.). The action is represented by the following symbols :—



### Experiments.

1. Repeat Exp. 1., Art. 22.
2. Let fall powdered antimony into a bottle of this gas ; the metal ignites spontaneously, and forms a beautiful shower of flame. Various other metals ignite spontaneously in this gas, and form *chlorides*.
3. Put a piece of red calico moistened with water

into a bottle of chlorine: the colour is speedily discharged.

### *Hydrochloric Acid*—HCl.

**63.** To obtain this acid in the gaseous state, introduce into a retort common salt and as much sulphuric acid as will form a thin paste; apply the flame of an Argand lamp, and receive the gas by displacement, as it is highly soluble in water. See Art. 54.

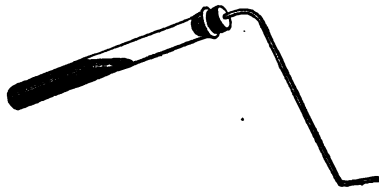
*Experiment.* Place a bottle of this gas over a bottle of ammoniacal gas: the gases combine and form dense white fumes of hydrochlorate of ammonia.

*Liquid hydrochloric acid* may be prepared in considerable quantities by transmitting a current of the gas through water; it may also be made on a small scale, after the manner of preparing nitric acid (see page 61.), taking care, in this case, to put water into the receiver *b*.



### *Cyanogen*—Cy, or $C_2N_2$ .

**64. Experiment.** Introduce a few grains of cy-



anide of mercury (HgCy) into a test-tube fitted with a cork and bent tube; apply the flame of a spirit-lamp: cyanogen gas is given off; ignite the gas as it issues from the small tube: it burns with a beautiful violet flame.

## SECTION VI.

COMPOSITION OF VEGETABLE SUBSTANCES. COMPOUND ORGANIC SUBSTANCES IN PLANTS. FERMENTATION. DIASTASE. GERMINATION OF PLANTS. STRUCTURE AND FUNCTIONS OF PLANTS. FOOD OF PLANTS.

## COMPOSITION OF VEGETABLE SUBSTANCES.

**65.** WHEN a piece of straw, or any dried vegetable substance, is held in the flame of a candle, the greater portion is consumed in the form of gases, and only a very small portion, called the ash, is left behind. That portion which burns away is called the *organic* part of the plant, and that which remains, the ash, is called the *inorganic* part. The organic part of plants consists of four elementary substances, viz. carbon, oxygen, hydrogen, and a small quantity of nitrogen. The inorganic part consists of the following earthy substances, viz. potassa, soda, lime, silica, magnesia, alumina, oxide of iron, oxide of manganese, sulphuric acid, phosphoric acid, and chlorine. Although the ash forms a very small part of plants, yet it seems to be as essential to their growth and existence as any of the elements composing the organic part. The proportion in which these substances are found varies in different plants, and even in different parts of the same plant. The following Tables, by Boussingault and Johnston, give the composition of the organic as well as of the inorganic parts of some of our most valuable plants.

When all moisture has been evaporated, 100 lbs.

of each vegetable substance is composed as follows :—

	Carbon.	Oxygen.	Hydrogen.	Nitrogen.	Ash.	
Wheat -	46·1	43·4	5·8	2·3	2·4	100
Oats - -	50·7	36·7	6·4	2·2	4·0	100
Peas - -	46·5	40·0	6·2	4·2	3·1	100
Potatoes -	44·0	44·7	5·8	1·5	4·0	100
Wheat straw	48·4	38·9	5·3	0·4	7·0	100
Oat straw -	50·1	39·0	5·4	0·4	5·1	100
Pea straw -	45·8	35·6	5·0	2·3	11·3	100

In 100 lbs. of ash we have the following composition :—

	Wheat	Oats.	Barley.	Wheat Straw.	Oat Straw.
Potassa - -	19	6·0	12	0·50	15
Soda - - -	20·5	5·0	12	0·75	trace
Lime - - -	8	3·0	4·5	7·00	2·75
Magnesia - -	8	2·5	8	1·00	0·50
Alumina - -	2	0·5	1	2·75	trace
Oxide of iron -	0	1·5	trace	0	trace
Silica - - -	34	76·5	50	81·00	80·00
Sulphuric acid -	4	1·5	2·5	1·00	1·50
Phosphoric acid -	3·5	3·0	9	5·00	0·25
Chlorine - -	1	0·5	1	1·00	trace
	100	100	100	100	100

66. Hence it appears that different kinds of plants must exhaust the soil of different proportions of inorganic matter: thus, for example, 100 lbs. of the of wheat carry off 19 lbs. of potassa and 34 lbs.

of silica, while that of barley only 12 lbs. of potassa and as much as 50 lbs. of silica. Thus it is that some land will suit one kind of vegetables and not another kind; and hence it is that two successive crops of *different* kinds of plants may grow on land, when two successive crops of the *same* kind would exhaust the soil of some of its most essential constituents. It has, however, been found, that when any one of the alkalies is absent from the soil, its place may be to a certain extent supplied by another alkali without injury to the vegetation: thus when a soil is deficient in potassa and soda, then lime (an alkaline earth) will in some measure supply their place in the ash of the plant.

**67.** As plants carry off, year after year, certain portions of organic as well as inorganic substances from the land in which they grow, it becomes necessary, in most soils, that these substances should be restored to the land in the form of manures.

#### COMPOUND ORGANIC SUBSTANCES IN PLANTS.

**68.** In the organic part of plants, the four elements of which it is composed are found in the plant in the form of distinct compounds; the most abundant of these are lignine or woody fibre, starch, gum, sugar, gluten, and albumen. The first four substances are composed of carbon and water only, and the two last substances contain nitrogen, in addition to carbon, oxygen, and hydrogen.

The composition of the first four substances is as follows:—

	Composition	may be represented.
Lignine	- $C_{12} H_9 O_9$	12 eq. carbon and 8 eq. water.
Starch	- $C_{12} H_{10} O_{10}$	12 eq. carbon and 10 eq. water.
Gum	- $C_{12} H_{11} O_{11}$	12 eq. carbon and 11 eq. water.
Grape Sugar	$C_{12} H_{12} O_{12}$	12 eq. carbon and 12 eq. water.

The only difference in the composition of these compounds is, that they contain different proportions of the elements of water.

Most of vegetable compounds are characterised by the following circumstances:— 1. By being composed of the same elements; 2. By the facility with which they undergo decomposition; 3. By the facility with which many of them are converted into each other, especially when a substance containing nitrogen is present; 4. By the impracticability of forming them by the direct union of their elements.

These distinct compounds, which exist ready formed in the vegetable, are called *proximate principles*; thus sugar and gum are proximate vegetable principles.

*Experiment.* Put some wheat flour in a fine muslin bag, and knead or work it with your fingers, while a small stream of water is poured upon it; continue the process until the water ceases to be milky: the substance remaining in the bag is a grey adhesive matter like birdlime, called *gluten*; allow the milky portion which has been washed from the bag, to subside; decant off the clear liquid: the white deposition is called *starch*; take the clear liquid and boil it: white flakes of *albumen* are formed, a substance very similar in its nature to the white of an egg. Gum and sugar are dissolved in the water.

Perform the same process with grated potato: in this case, fibrous matter is left in the bag, the other portions being the same as in the preceding experiment.

69. Lignine, starch, gum, and sugar, being so similar in composition, may readily be converted into each other. Thus, for example, starch may be

converted into gum by roasting at a temperature above that of boiling water; lignine may be converted into gum by the action of strong sulphuric acid; and the gum thus formed may be converted into sugar by adding water, and boiling the mixture for some hours; and so on to other cases of transformation.

### *Experiments.*

1. Dissolve some starch in boiling water: a thick jelly is formed, which after being dried has the appearance of glue; this jelly is insoluble in cold water, and is rendered blue by the addition of a solution of iodine (see Exp. 2., Art. 21.). To the thick solution of starch add an infusion of vegetated barley of the malting: the starch grows more liquid, and in a short time its consistence entirely disappears; evaporate to dryness, and a *yellow* jelly-like mass is obtained, which is now readily dissolved by *cold* water, whereas starch is insoluble in *cold* water. To a solution of this substance add a solution of iodine: a red wine colour is produced. This yellow substance is a gum called *dextrine*; it is used in the place of gum-arabic for stiffening calico. There is evidently some active agent in the vegetating barley, which has produced these changes in the starch: this agent has been called *diastase*.

2. Boil some diluted sulphuric acid (one of acid to twelve parts of water) in a porcelain dish; add gradually some starch paste: the starch is dissolved; test a portion of the solution by means of a solution of iodine: a red wine colour is produced, as in the last experiment; continue the boiling for a short time longer, and the iodine will cease to produce any change of colour. Take the liquid in the eva-

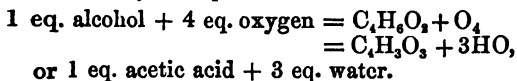
porating dish, and add to it powdered chalk until the acid is neutralised, and allow the sulphate of lime to subside : the clear liquid is sweet, and crystals of *sugar* may be obtained by evaporating a portion of the water by a slow heat. In this process no gas is given off, and the acid suffers no change. The only difference in the composition of starch and sugar is, that the latter contains more of the elements of water than the former.

Berzelius designates this peculiar action exerted by the sulphuric acid in converting starch into sugar the *catalytic force*, or the force of *catalysis*.

**70. Fermentation.** This term is used *generally* to express those changes that are spontaneously effected in organic substances by the re-action of their elements. Thus, when a solution of grape sugar, to which ferment or common yeast has been added, is kept for some time at a moderate heat, the mixture froths up, in consequence of the escape of carbonic acid gas, the sweet taste of the solution gradually disappears, and when the *fermentation* has ceased, spirit or alcohol is found in the water. This spirit is given off in a concentrated form by evaporation at a temperature below that of boiling water. Alcohol ( $C_4H_6O_2$ ) contains less oxygen and carbon than sugar; hence the escape of carbonic acid in order to change the sugar into *alcohol*. Thus sugar, or  $C_{12}H_{12}O_{12}$ , becomes  $2C_4H_6O_2$ , or 2 eq. alcohol and  $4CO_2$ , or 4 eq. carbonic acid. Yeast, as well as all substances which have the property of *inducing* or exciting fermentation, contains nitrogen, in addition to carbon, oxygen, and hydrogen.

**71.** When a mixture of diluted spirit and yeast is exposed to the air, oxygen is absorbed, and *acetic acid* or vinegar is formed. The composition of dry acetic acid is  $C_4H_3O_3$ ; that is, it may be repre-

sented by 4 eq. carbon and 3 eq. water. Hence the action may be represented as follows:—



In both of these cases of fermentation the yeast merely acts as a stimulating agent.

**72.** Besides the proximate vegetable principles already enumerated, there are several vegetable acids, oils, fatty matters, and the peculiar substance called diastase, which produces an important action in relation to the growth of plants.

*Vegetable acids.* The most common vegetable acids are, acetic acid (vinegar), malic acid (the acid of apples), oxalic acid (from common sorrel), tartaric acid (in grapes), citric acid (the acid of lemons).

#### GERMINATION. DIASTASE.

**73.** When a seed is planted it begins to sprout, that is, it shoots a sprout upwards into the air, and sends a root downwards into the soil. At this stage of the life of the young plant it must live upon the starch and gluten contained in the seed alone. In order to render these substances soluble in water, and thereby available for the food of the plant, there is formed out of the gluten, at the base of the germ, the peculiar substance called diastase. This substance renders the starch soluble in the sap, and it is thus conveyed to the shoot and root of the young plant. The starch in this state of solution becomes sugar. As the plant advances in its growth it begins to have leaves, and at this stage the sugar is changed into woody fibre, which forms the stem.

By the time the starch and gluten are exhausted from the seed, the plant has acquired all the functions necessary for taking up food from the air and the soil. A similar process takes place in the formation of malt, where the germination of the barley is stopped when the sugar is formed.

#### STRUCTURE AND FUNCTIONS OF PLANTS. FOOD OF PLANTS.

**74.** A complete plant has three parts which are essential to its growth: a root, which throws out fibres into the soil; a trunk or stem, which rises into the air; and leaves, which present an extended surface to the action of the air. Each of these three parts performs peculiar functions or offices in the growth of the plant.

1. The *trunk* or stem consists of three parts: in the centre is the *pith*, next the pith is the *wood*, and the *bark* incloses the whole.

The *pith* consists of very small horizontal tubes; the *wood* and *inner bark* are made up of longitudinal tubes connected together for conveying the sap between the roots and leaves; the vessels in the wood convey the sap from the roots to the leaves, and the vessels in the inner bark convey the sap from the leaves to the roots: thus in a growing plant there are currents of sap continually ascending and descending.\*

2. The *root* on leaving the stem has the same structure as the trunk; but the finely-extended tendrils consist of one white uniform spongy mass, for the purpose of absorbing liquid food from the soil.

\* The ascent of the sap probably, in some measure, depends on the principle of *endosmose* and *exosmose*. (See page 29. of the Treatise on Hydrostatics.)

**3.** The *leaf* consists of fibres, which are continuations of the wood, together with the green portion, which is a continuation of the bark. The under part of the leaf is full of pores, which communicate with the hollow tubes of the inner bark.\* It has already been explained (Exp. 6., Art. 15., and Art. 18.) that in the day-time the leaves are continually absorbing carbonic acid gas from the air, and throwing off oxygen : thus carbonic acid is decomposed by the plant—the carbon is retained as food, while the oxygen is rejected. The reverse of this process is going on at night, but so slowly as scarcely to interfere with the general effect. Carbonic acid also enters the plant through the roots. Some *suppose* that carbon enters the plant by the roots in the form of *ulmic acid*, a substance composed of carbon and water only.

**75.** The elements composing the organic part of plants are always absorbed in a state of combination, and the substances forming the inorganic part must be in a state of solution, in order to be sucked in by the roots. The food of plants must contain the various elements which enter into their composition. In general, the substances which afford this food, are carbonic acid, water, and ammonia, derived from the air as well as the soil ; and certain saline and earthy substances, derived exclusively from the soil. Light and heat (and probably electricity) stimulate the functions of plants, and are absolutely necessary to their growth and full development. Light is also essential to the formation of the colouring matter in plants.

It will now be easy to see how the plant should

\* For a full description of *all* the parts and functions of plants, see Balfour's "Botany."

form woody fibre, starch, sugar, gum, or vinegar, all of which substances consist of carbon and water only, united in different proportions. Ammonia and nitric acid supply the plant with nitrogen.

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## SECTION VII.

SOILS. THEIR COMPOSITION. ORGANIC AND INORGANIC PARTS. SALINE AND EARTHY PARTS. PHYSICAL CHARACTER OF SOILS. TO SEPARATE THE SAND FROM THE CLAY. TO DETERMINE THE QUANTITY OF LIME, OF ORGANIC MATTER, AND OF SALINE MATTER, IN A SOIL. ORIGIN OF SOILS. MECHANICAL PROPERTIES OF SOILS. CHEMICAL PROPERTIES OF SOILS.

### COMPOSITION OF SOILS.

**76.** SOILS, like plants, are composed of organic as well as of inorganic matter.

The ORGANIC PART OF SOILS is chiefly derived from the remains of vegetable and animal substances. Peaty soils contain a large proportion of organic matter, while good wheat lands contain only about one-twentieth of their whole weight. This organic matter in the soil has been called HUMUS, which, by the action of alkaline substances, is resolved into ulmic and humic acids. As the vegetable matter undergoes decay, this organic portion of the soil also gives to the land the various inorganic substances found in its ash.

**77.** The INORGANIC PART OF SOILS consists of

certain *saline* soluble substances, and of certain *earthy* insoluble substances.

1. The *saline soluble substances* consist, in general, of common salt, sulphates of soda and magnesia, gypsum, with small portions of the nitrates of potassa, soda, and lime, and of the chlorides of calcium, magnesium, and potassium, together with ammoniacal salts. From these soluble compounds the plant obtains nearly all the saline matter contained in its ash. The rain dissolves these saline substances, and carries them into the subsoil; but in dry warm weather, they reascend to the surface, and are thus brought in contact with the roots of the growing plant. Thus fine warm weather accelerates the ripening of corn and other valuable grain.

2. The *earthy insoluble substances* in the soils never constitute less than nine-tenths of their whole weight. The *principal* ingredients of this earthy matter are *silica* in the form of sand, *alumina*, mixed with sand, in the form of *clay*, and *carbonate of lime*. Where the soil has a red colour, the *oxide of iron* is generally present. Minute traces of *phosphate of lime* may also be detected in most of good soils.

#### PHYSICAL CHARACTER OF SOILS.

78. The relative proportions of sand, clay, and lime in a soil give it a peculiar physical character. When a soil contains only a small proportion of clay, it is called a *sandy soil*; when the quantities of sand and clay are nearly equal, it is called a *loamy soil*, or *clay loam*, according as the quantity of sand is greater or less than the clay; when the clay is much in excess, it is called *clay loam*, or *strong clay*, as the case may be. Good arable land rarely contains more than one-third part of its weight of clay.

**79.** *To separate the sand from the clay in a soil.* Take about half an ounce of soil, and boil it in about half a pint of water, in a porcelain dish, until it is completely diffused through the water ; after shaking let the mixture stand for a minute, to allow the sand to settle to the bottom of the vessel, while the clay remains suspended in the fluid ; pour off the water with the floating clay into another vessel, and allow the clay now to settle. The sandy portion of the soil will be found in the first vessel, and the clayey portion at the bottom of the second. The sand and clay may now be dried and weighed separately, and the relative weights will give the proportion in which they subsist in the soil.

**80.** If a soil contains more than one-twentieth of its weight of carbonate of lime, it is called *marl* ; and if more than one-fifth, it is called *calcareous soil*.

*To determine the quantity of lime in a soil.* Take 100 grains of the soil (which has been previously heated to redness, to destroy the vegetable matter) and diffuse it through about half a pint of distilled water ; add about an ounce of hydrochloric acid, and allow the mixture to stand for a few hours, observing to stir it time after time. Bubbles of carbonic acid are given off. After the action has ceased, pour off the clear liquid ; dry and then heat the residue to redness, and weigh it : the loss is nearly the weight of lime and carbonate of lime in the soil.

**81.** *To determine the quantity of organic matter.* Dry about an ounce of the soil on paper in an oven, at a heat which does not char the paper ; burn about 200 grains of this dry soil : the loss is nearly the weight of the organic matter contained in it.

**82.** *To determine the quantity of saline matter.*

Take 2 lbs. of dry soil, and boil it in about a quart of distilled water; after allowing the solid matter to subside, pour off the clear liquid, and evaporate to dryness at a moderate heat; weigh the residue, and it will give the quantity of soluble saline matter in the soil. In a good soil this saline matter may weigh, upon an average, about 20 grains.

#### ORIGIN OF SOILS.

**83.** Soils owe their origin to the disintegration or gradual crumbling down of rocks, by the action of water, frost, air, and various chemical agents. Hence soils, in general, derive their peculiar character from the geological strata upon which they lie, or from the nature of the rocks in the adjacent hills or mountains.

#### MECHANICAL PROPERTIES OF SOILS.

**84.** Sandy and marly soils are heavy, while peaty soils are light. Strong clays and peaty soils absorb and retain moisture; hence they are damp and cold; hence, especially, the necessity for draining such soils. Sandy soils neither absorb nor retain much moisture; hence such soils become scorched with the heat of summer, and the plants growing upon them are burned up. In rainy seasons, however, sandy soils frequently sustain a luxuriant vegetation, while the plants upon a clayey land almost perish from the excess of moisture.

**85.** Heat causes clay and peat to contract; in doing so, the soil compresses the roots of the plants, and prevents the access of air, and thus the growth of the plant is retarded.

**86.** The absorbent power of clay is useful in a soil, for during the hot and dry season of the year,

in the cool period of the night, the clay absorbs the dew that falls upon it, and retains the moisture with great tenacity.

**87.** In order that plants may come to perfection, it is necessary that the soil on which they grow should attain a certain degree of warmth. Damp lands are cold, for the continual evaporation of the moisture carries off the heat of the sun; hence the necessity of drainage.

**88.** These observations show the value of a due admixture of clay and sand in order to form a mixture having all the mechanical qualities of a fertile soil, where the earthy constituents are so adjusted that "the loose and porous qualities of the one are corrected by the plastic and retentive qualities of the other." It is a remarkable fact, that a mixture of alumina, silica, and lime, absorb gaseous matter as well as moisture, better than any of these earths taken by itself.

#### CHEMICAL PROPERTIES OF SOILS.

**89.** Soils not only sustain a plant in an erect position and afford it food, but they are the medium in which various chemical actions are gradually and constantly going on, in the preparation of different substances essential to the growth of plants. Thus lime is constantly decomposing vegetable and animal matter in the soil, and thereby preparing food for the plant. Thus organic substances in the soil aid in absorbing ammonia and carbonic acid from the air. Thus little grains of alkaline silicates are gradually reduced to powder, and in this state water dissolves the alkaline matter. (See Exp. 1., Art. 28.)

**90.** A fertile soil should not only contain all the

elements essential to the growth of a plant, but they should exist in a due proportion. A deficiency of one substance, or an excess of another, may equally contribute to deteriorate the quality of the land. Hence the utility of artificial applications to land, whereby the farmer is enabled to supply what may be deficient, or in some degree to neutralise the influence of what may be in excess. The following analyses of three different soils, by Dr. Sprengel, afford a striking illustration of these remarks.

1000 parts of each soil contained as follows :—

	No. 1.	No. 2.	No. 3.
Fine earthy and organic matter	937	839	599
Silicious sand	45	160	400
Saline soluble matter	18	1	1
	<hr/> 1000	<hr/> 1000	<hr/> 1000

1000 parts of the fine earthy and organic matter contained :—

	No. 1.	No. 2.	No. 3.
Organic matter	97	50	40
Silica	648	833	778
Alumina	57	51	91
Lime	59	18	4
Magnesia	8.5	8	1
Oxide of iron	61	30	81
Oxide of manganese	1	3	$\frac{1}{2}$
Potassa	2	trace	trace
Soda	4	—	—
Ammonia	trace	—	—
Chlorine	2	—	—
Sulphuric acid	2	$\frac{3}{4}$	—
Phosphoric acid	4.5	$1\frac{1}{2}$	—
Carbonic acid	40	$4\frac{1}{2}$	—
Loss	14	—	$4\frac{1}{2}$
	<hr/> 1000	<hr/> 1000	<hr/> 1000

No. 1. is a highly fertile soil, which had grown corn and pulse crops *without* the application of any manure. This soil seems to contain all the essential constituents of plants. No. 2. is a fertile soil which required to be manured with gypsum. The analysis indicates a deficiency of soluble saline matter, with only traces of potassa, soda, and sulphuric and other acids. No. 3. is a barren soil; it is deficient in organic matter; potassa, soda, &c. are almost wanting; lime, oxide of iron, and silica seem to be largely in excess. In order to render this soil productive, it would require, not only to have added those substances which are absent, but some other substances which would tend to neutralise the matters in excess.

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## SECTION VIII.

IMPROVEMENT OF SOILS. MECHANICAL OPERATIONS: DRAINING, PLOUGHING, ETC. MANURING: VEGETABLE, ANIMAL, AND MINERAL MANURES. SPECIAL MANURES. ROTATION OF CROPS. FALLOWING. IRRIGATION.

### IMPROVEMENT OF SOILS.

**91.** LAND may be improved by working it, that is, by mechanical operations, such as draining, ploughing, &c.; or by improving the quality of the soil by the application of manures.

#### MECHANICAL MEANS OF IMPROVING LAND.

**92.** *Draining.* It has already been shown (Art.

87.) that damp lands are cold and unproductive. The first consideration, therefore, with the farmer in reference to such soils is to have all redundant moisture carried off by means of drains. The advantages of drainage are further shown by the following circumstances. When there is too much water in a soil, the food of the plant is either washed down to the subsoil, or it enters the roots in a very diluted state. When a soil has been drained and ploughed, it is no longer close and adhesive, but permits the air to penetrate through it, and the roots to extend themselves in all directions. Moreover, a more healthful decomposition of the organic matter goes on in dry soils than in damp ones.

There are few soils which may not be benefited by drainage. It is especially beneficial to damp clay and peaty soils. When the soil is a clay with sand or gravel for the subsoil, it will be sufficient if the surface is drained: but when the soil is sandy, with clay for the subsoil, the drain should go down into the subsoil, otherwise the land will be damp and cold. To prevent the soil being washed away, the fall of drains should be gentle. Land should always be drained some time before ploughing. Drain pipes made of porous burnt clay fitting into each other are now generally adopted for agricultural purposes.

93. *Ploughing* in general, especially combined with drainage, allows water, air, and other gases to come in contact with the roots of the plants, destroys unhealthful acidity in the soil, and promotes the decomposition of vegetable matter.

94. *Subsoil* and *deep-ploughing* especially bring new mineral manure, such as lime, to the surface. Agriculturists consider that the subsoil plough

should not be used until after the land has been drained for one year. The reason of this must be obvious: damp soils are merely cut by the plough, whereas dry soils are broken to powder when a heavy plough passes through them.

#### MANURING AS A MEANS OF IMPROVING SOILS.

95. Manures are divided into three classes; viz. vegetable manures, animal manures, and mineral manures.

#### VEGETABLE MANURES.

96. These manures serve to open the pores of the land, and to supply organic as well as inorganic food to plants. Vegetable matter may be used as a manure either in the *green* state or in the *dry* state.

*Green manures.* When green vegetable substances are put into the soil, they undergo a rapid decay, yielding a speedy supply of food to the growing plant; on the contrary, dry manures decay more slowly, but act more permanently upon the land. The cleanings of ditches, hedge-sides, &c., turnip and potato tops, mixed with earth, and formed into a *compost heap*, constitute an enriching application to the soil. In some parts of this country turnip seed is sown at the close of harvest, and at the end of two months the green crop is ploughed into the land. Sea-weeds form a valuable green manure.

97. *Dry manures.* Dry vegetable substances, such as straw, saw-dust, &c., decay very slowly; it is desirable, therefore, before applying such substances to the land, that they should be mixed with

some matter which tends to promote fermentation. The droppings of cattle, urine, or animal substances of any kind, are used for this purpose. Saw-dust mixed with soil and common weeds, laid up in a compost heap, and time after time watered with the liquid manure of the farm-yard, is converted into a valuable vegetable mould. If the fermentation be not carried beyond a certain point, this compost exercises a gradual and prolonged action on the growing plants; on the contrary, if it be laid on the land when in a complete state of fermentation, the action is immediate; hence the application of the latter kind of manures to turnips and other crops which require to be brought into a condition of rapid growth. *Charcoal-powder, malt-dust, bran, rape-dust, soot, tanner's bark, &c.*, are the most common dry manures in use.

## ANIMAL MANURES.

98. Animal manures are the most energetic in their action, in consequence of the nitrogen they contain, which exists in them in the form of ammoniacal salts: these salts are amongst the most powerful agents in promoting vegetation. The value of guano as an application to the soil depends chiefly on the quantity of ammonia which it contains. Urine also owes its efficacy to the large quantity of the salts of ammonia in its composition. According to Liebig, the air immediately in contact with the soil contains small portions of ammonia, which is being continually absorbed by the soil. The soluble portion of manures is most valuable, in consequence of the volatile substances which it contains; and hence the intelligence and industry of a farmer is shown by the care he takes of his

dung-heap and liquid manure. The urine of the cattle should be collected into a tank sunk in the ground, and covered over to prevent the rain-water from mixing with it. In warm weather the mixed manure heap, or compost heap, should be watered, and a free current of air allowed to pass over it, in order to check, in some degree, the process of fermentation, which causes the carbonate of ammonia to escape into the air. In order still further to secure the volatile matters, the heap should be covered over with a layer of soil, or, in other cases, with the sulphate of lime; these earths absorb and fix the vapours, and are thus converted into valuable applications to land. Quicklime should never be put into the compost heap, for it decomposes the salts of ammonia, and thus the most valuable portion of the manure would be dissipated into the atmosphere. As there is always a loss during fermentation, the judgment of the farmer must be exercised as to the proper time for laying the fermenting manure upon his land: this time must, in some degree, depend upon the nature of the soil and crops to be reared. To cold soils, for example, fully fermented manure is most valuable, as it tends to warm the soil, and to stimulate the growth of the plant.

99. Boussingault gives the following analysis of an average farm-yard manure :—

In 100 parts of the manure we have

Carbon	-	-	-	-	7.41
Oxygen	-	-	-	-	5.34
Hydrogen	-	-	-	-	0.87
Nitrogen	-	-	-	-	0.41
Salts and earthy substances	-	-	-	-	6.67
Water	-	-	-	-	79.30

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100.00

**100.** *Bones* not only contain animal matter, but also a large quantity of earthy substances; hence the value of this substance as a manure. The composition of the bones of the cow is as follows:—

Phosphate of lime -	-	-	55½
Phosphate of magnesia -	-	-	3
Soda and common salt -	-	-	3½
Carbonate of lime -	-	-	3½
Fluoride of calcium -	-	-	1
Gelatine -	-	-	33¼
<hr/>			
			100

Bones are used in the form of bone-dust and broken bones; the former is more immediate in its effect, the latter more permanent. Bones are most beneficially applied to turnip crops.

**101.** *Blood and muscle*, forming the refuse in the butcher's heap, mixed with marl and other earthy substances, have been found to be a powerful manure. *Horn, hair*, and *wool* are used in a similar manner

**102.** *Animal excrements.* Horse-dung is more valuable than cow-dung, in consequence of the cow discharging more urine than the horse, which carries off soluble organic matter. The horse-dung is a *hot* manure, while cow-dung is *cold*. The horse-dung, as already shown, is chiefly used for bringing other manures into a state of fermentation. The dung of pigs, like that of the cow, is soft and *cold*.

**103.** *Nightsoil* is considered to be one of the most powerful of all solid animal manures.

**104.** *Pigeons' dung.* The dung of birds is a very active manure; it unites the qualities of the liquid as well as of the solid excrements of other animals: it is usually applied with a mixture of coal ashes.

**105.** *Guano* is chiefly the excrement of sea-fowl;

it has been found in vast quantities on the rocky parts of the coast of Peru, and at Ichaboe, an island on the west coast of Africa. This manure has been brought to this country, and sold for 9*s.* to 12*s.* a cwt. It has been successfully applied to crops of turnips, potatoes, oats, barley, &c. It is applied in different proportions, varying from 1 to 4 cwts. per acre. When applied to the land, it is mixed with fine dry sand, or with gypsum. Probably no manure contains so many of the ingredients necessary to the growth of plants as guano. The following analysis of African guano was made by the late Dr. Fownes:—

Oxalate of ammonia, uric acid, traces of carbonate of ammonia, and animal matter	-	66·2
Phosphate of lime and magnesia	-	29·2
Phosphates and chlorides of alkalies	-	4·6
		<hr/>
		100·0

**106.** *Urine* is rich in various compounds of ammonia; it should be applied in a fresh state, for when it putrefies a considerable loss of urea takes place. It may be thrown over the land by means of a water-cart. When sulphuric acid is added to urine it combines with and fixes the ammonia: by evaporation a dry powder is obtained, which is called *sulphated urine*; this is said to form a valuable artificial manure.

#### MINERAL MANURES.

**107.** *Lime, shell-sand, and marl.* Lime is the most important of all the mineral applications to land. It serves a mechanical purpose by giving a proper consistency to soils, and it acts chemically by decomposing various organic substances, at the

same time absorbing and fixing their gaseous products, and rendering vegetable as well as mineral substances soluble which were not so before.\* Mr. Moffat, in an able paper (published in the "Journal of the Northumberland Agricultural Society" for the year 1849), adduces the following experiment to illustrate the mode in which lime acts on the soil: —

*Experiment.* "Take some saw-dust, or any fibrous matter, and boil it in water so as to extract all its soluble matter; wash it well with cold water, and strain, so as to leave it only in a moist state; then add to it one-fifth part of caustic lime, and close the mixture up in a bottle for two or three months. After this period you will find the lime to have assumed a brownish colour, effervescent when vinegar is poured upon it, which indicates the presence of carbonic acid; and when water is again boiled with the mass, it will gain a fawn colour, and by evaporation leave a fawn-coloured powder, consisting of lime combined with vegetable extract. The saw-dust previous to the action of the lime was perfectly insoluble in water; it is now converted into a brownish powder, which dissolves in large quantity in water. Now this is precisely an example of the change produced by the action of lime in a caustic state upon the insoluble fibrous matters of the soil." Mr. Moffat further observes: — "Caustic lime decomposes all the salts and combinations of ammonia, combining with their acids

\* Insoluble compounds of silica and potassa exist in many of our rocks: now when these earths are crushed and mixed with lime and water, it has been found that, after a certain time, the silica and potassa are converted into a soluble form. No doubt these changes take place, to a limited extent, in the soil.

by reason of its stronger alkaline affinity, and dissipating the ammonia into the atmosphere ; hence lime should never be applied with guano, nor farm-yard dung, as a great portion of the nutritive quality of these manures resides in the salts of ammonia they contain." When vegetable matter abounds in a soil, a considerable portion of lime may be used to promote the decomposition. Stiff clay lands, after draining, should be well limed ; on the contrary, light lands, where there is neither much moisture nor vegetable matter, do not require such a quantity. Striking effects are produced by a due application of lime to pasture and arable lands.

The effects of lime gradually disappear, and after a few years the land returns to its original state, unless fresh lime be added.

Lime is removed from the soil,—first, by sinking through the loose soil ; secondly, by rains which wash it away ; and thirdly, by the crops carrying off certain portions of lime in the form of the carbonate.

**108.** *Marl and shell-sand*, besides other fertilising matters, contain a large quantity of carbonate of lime ; their action upon land is similar to that of *mild* lime. Sulphuret of iron (iron pyrites) is found in some soils. This insoluble substance has no chemical action, but when it has been for a length of time exposed to the action of the air, it absorbs oxygen, and is converted into sulphate of iron (green vitriol), which is highly soluble, and injurious to plants. Now the addition of carbonate of lime decomposes this salt, forming sulphate of lime and the inert oxide of iron, with the escape of carbonic acid gas.

**109.** *Sulphate of lime* may be used with advan-

tage for all kinds of crops, but it is especially applicable to clover, pea, and bean crops. The sulphates generally supply sulphur to plants.

**110.** *Sulphate of magnesia*, as a top dressing, has been applied with great benefit to young wheat.

**111.** *Sulphate of soda* (Glauber salts) has been beneficially used for turnip crops; and, mixed with nitrate of soda, it has given abundant crops of potatoes.

**112.** *Chloride of sodium* (common salt) has generally a fertilising influence on high or sheltered lands situated at a distance from the sea.

**113.** *Kelp* (the ash of sea-weeds) and *wood-ash* are well known to have a beneficial action on all kinds of soils.

**114.** *Chloride of potassium* (the residue of the nitre refiners) is sometimes used as a dressing for grass-land.

**115.** *Nitrates of potassa and soda*. These have been found especially beneficial to young plants. The nitric acid which they contain supplies nitrogen to the vegetable, and the potassa and soda are equally fertilising; applied at the rate of about 1 cwt. per acre, they promote the growth of young corn and grass.

**116.** *Gas-liquor* contains a large quantity of ammonia; it therefore forms, when diluted with five or six times its weight of water, a superior manure for grass-lands or crops generally. Sulphuric acid, or gypsum, is sometimes added, to fix the ammonia in the gas-liquor.

**117.** *Special manures*. As plants differ in their composition, so different plants evince a predilection for different kinds of food. Ammonia, nitrate of soda, and lime, promote the growth of all plants. Lime, especially in well drained soils, tends to bring

the fruit or seeds of plants to perfection, and thus to bring in an early harvest. Gypsum promotes the growth of red clover, and phosphate of magnesia has a similar effect upon potatoes ; and so on to other cases.

The specific action of particular manures on the growth of certain plants is a remarkable and interesting fact. Even certain manures promote the development of particular parts of the plant ; thus, for example, manganese added to the soil improves the flowers of the rose bush.

**118. *Mixed saline manures.*** A mixture of lime and common salt is recommended as an excellent manure. A mixture of sulphate and nitrate of soda, as a top dressing, has been found to produce remarkable effects on the growth of potatoes ; and so on to other cases. It appears that the application of mixed saline substances is calculated to produce more beneficial results than when these substances are used alone. Hence it is that guano (which contains several saline substances) is found to act so beneficially on almost every kind of crops.

#### ROTATION OF CROPS.

**119.** The composition of soils should have a relation to the kind of plants which they are intended to grow. It is well known to botanists that certain species of plants grow naturally on soils of a particular formation ; thus, mare's-tail grows abundantly on the margin of rivers where silica abounds. When a particular species of plant has been grown for a length of time on a soil, that soil becomes exhausted of the inorganic matter adapted to the growth of that particular plant. Now different plants extract from soils different proportions of

the inorganic matter contained in them. (See Art. 66.) Hence a succession of crops of different vegetables may be raised upon the same soil, when two successive crops of the same vegetable could scarcely be reared. Thus barley grows well after a crop of turnips; oats after a crop of grass; wheat after crops of beans and potatoes. The following is a specimen of a six years' rotation of crops\* :—

1. Wheat; 2. Turnips; 3. Barley; 4. Seeds;  
5. Oats; 6. Potatoes.

The following general rule should be observed in the choice of the rotation of crops: viz. "plants which require *chiefly* the same kind of food should not be grown in succession;" thus plants which are grown for their roots, grow best after those which are grown for their seeds.

Clover adds fertility to the soil, and hence an abundant crop of corn may be obtained after a crop of clover. In this way the use of clover has to a great extent superseded the system of fallowing.

**120. Fallow.** When land has been exhausted by a succession of crops, its exhausted resources are resuscitated by manuring, and allowing it to lie dormant, exposing it at the same time (by ploughing, &c.) to the action of the air and moisture.

**121. IRRIGATION.** When water is allowed to remain on land, it is injurious to vegetation; but the occasional flow of water over the surface of lands, as in our irrigated meadows, carries with it various fertilising substances.

\* Antisell's "Chemistry."

LIST OF CHEMICALS AND APPARATUS ADAPTED TO  
THE EXPERIMENTS CONTAINED IN THIS TREATISE.

*List of Chemicals.*

				s.	d.
Acid, Arsenious	-	-	- oz.	0	3
" Hydrochloric	-	-	- lb.	0	3
" Nitric	-	-	- lb.	1	4
" Oxalic	-	-	- oz.	0	3
" Sulphuric	-	-	- lb.	0	3
" Tartaric	-	-	- oz.	0	3
Alum	-	-	- lb.	0	3
Ammonia, Liquid, concentrated	-	-	- lb.	1	6
" Carbonate	-	-	- lb.	1	0
" Hydrochlorate	-	-	- lb.	1	0
" Oxalate	-	-	- oz.	1	0
Antimony, Metallic	-	-	- lb.	1	6
" Sulphuret	-	-	- lb.	1	0
Barium, Chloride	-	-	- oz.	0	2
Baryta, Nitrate	-	-	- oz.	0	2
Camphor	-	-	- oz.	0	8
Clay, Stourbridge or Pipe, for luting	-	-	- lb.	0	2
Copper Leaf	-	-	book	0	3
" Nitrate	-	-	- oz.	0	3
" Sulphate	-	-	- lb.	0	6
Distilled Water	-	-	per gall.	0	6
Gold Leaf	-	-	book	1	9
Iodine	-	-	- oz.	2	0
Iron, Sulphate	-	-	- oz.	0	3
" Sulphuret	-	-	- lb.	0	6
Lead, Acetate	-	-	- lb.	0	9
" Oxide, Litharge	-	-	- lb.	0	6
Lime, Hydrochlorate	-	-	- oz.	0	3
Litmus	-	-	- oz.	0	6
Magnesia, Sulphate	-	-	- lb.	0	6
Manganese, Black Oxide, in powder	-	-	- lb.	0	3
Mercury	-	-	- lb.	5	6
" Chloride (corrosive sublimate)-	-	-	- oz.	0	6
by decan. Nitrate	-	-	- oz.	1	0
phorus	-	-	- oz.	0	9

			s	d
Platinum, Wire and Sheet	-	drachm	0	5
Potassa, fused in pipes	-	- oz.	0	6
" Carbonate	-	- lb.	0	9
" Chlorate	-	- oz.	0	4
" Bichromate	-	- oz.	0	2
" Nitrate	-	- lb.	0	8
" Prussiate	-	- oz.	0	3
Potassium	-	grain	0	1
Silver, Nitrate, Crystals	-	drachm	0	8
Soda, Carbonate	-	- lb.	0	3
" Sulphate	-	- lb.	0	6
Spirit, Pyroligneous, for spirit-lamp	-	pint	1	6
Sulphur, Sublimed	-	- lb.	0	3
Tin Foil	-	- oz.	0	3
Tincture, Galls	-	- oz.	0	4
" Litmus	-	- oz.	0	6
" Red Cabbage	-	- oz.	0	6

### *List of Apparatus.*

- Bladders, plain, 6d. each ; mounted, 1s. 6d.  
 Cork Borers, set of five, 2s. 6d.  
 Crucibles, fire-clay, 4d. a dozen.  
 Evaporating Basins, from 6d. to 2s. each.  
 Filtering Paper, from 1s. 6d. to 2s. per quire.  
 Flasks, from 6d. upwards.  
 " with tubes for making gases, from 1s.  
 Furnace Iron, with chimney, 6s.  
 " " with sand-bath, &c. 30s.  
 " Chauffers, 2s. 6d. each.  
 Funnels, glass, from 6d. to 2s. each.  
 Gas Jars, plain, 1s. each.  
 " stopped, 1s. 6d. each.  
 " capped, 2s. each.  
 Gas-holder, small, 1l. 2s.  
 The Author's Gas-holder, with Oxy-hydrogen Blowpipe,  
 1l. 4s.  
 Ladles, Iron, for supporting ignited Phosphorus, &c., 6d. each.  
 Lamps, Spirit, 6d. each.  
 " Argand, oil, with chimney, 5s. 6d.

Mortar and Pestle, Wedgewood, 2*s*.  
Pneumatic Trough, 7*s*. to 10*s*.  
Test or Precipitating Glasses, 6*d*. each.  
Retort Stands, iron, three rings, 2*s*. 6*d*. each.  
Retorts, glass, from 9*d*. to 2*s*. 6*d*. each.  
Retort, iron, for making oxygen, 10*s*.  
Receivers, glass, 8*d*. to 1*s*. 6*d*. each.  
Scales and Weights, from 2*s*. 6*d*. to 4*s*.  
Stirring Rods, glass 1*s*. 6*d*. per dozen.  
Stop-cocks, brass, 2*s*. 6*d*. each.  
" jets, 10*d*. each.  
" connectors, 10*d*. each.  
Test-tubes, 3*s*. per dozen.

THE END.

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